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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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All communications should be addressed to the SECRETARY, 61, High Holborn, W.C. 1. O 667

UNIVERSITY OF BRISTOL.
DEMOBILISATION.

Special Regulations have been

made to allow intending students who have served in the war or in the scientific service of the war to be admitted to matriculation by vote of Senate on their educational qualifications, without formal examination; and also to allow of such students entering the University in January if candidates in Arts; in January, or between January and May, if candidates in Science, Medicine, Dental Surgery or Engineering; and if grounds be shown, counting their first year's attendance as though it had commenced in October. Engineering students in special cases may be allowed to count one whole year's attendance.

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Tenders must be in the form contained in the particulars of sale, and should be delivered under seal at the offices of Messrs. Fuller, Horsey, and Co., not later than Four p.m. on TUESDAY, December 10th, 1918.

Particulars, with plans and conditions of sale, are in course of preparation, and when ready may be obtained (price 5s. per copy) of FULLER, HORSEY, SONS, & CASSELL, 11, Billiter Square, London, E.C. 3. O 529

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Tenders, which must be on the form contained in the Particulars of Sale, should be delivered at the Auctioneers' Offices by Four p.m. on THURSDAY, December 5th, 1918.

The Works may be viewed by orders only, to be obtained of the Auctioneers, and Particulars with Conditions of Sale had of H. G. IVENS, Esq., Solicitor, High Street, Kidderminster, or of Messrs. FULLER, HORSEY & CO., Mechanical Auctioneers and Valuers, 11, Billiter Square, London, E.C. 3. O 530

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PURCHASE as a going concern of the well-established business of the ANCHOR CHAIN CO., Oldham, manufacturers of all kinds of textile chains, motor chains, stampings, and steel press work generally. Tenders to be sent in not later than December 2nd.—Full particulars, with card to view, may be obtained from Messrs. HARRY L. PRICE & CO., Accountants, 15, Fountain Street, Manchester. O 598

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Tenders made out on the Forms to be supplied by the Company should be delivered, under sealed cover, endorsed "Tender for Roof Principals, &c., Belfast," to the undersigned not later than 10 a.m. on Monday, the 9th December, 1918.

The Directors do not bind themselves to accept the lowest or any tender.

T. MORRISON, Secretary.

Secretary's Office,
Amiens Street Station,
DUBLIN, 18th November, 1918. O 725

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E. SALTER DAVIES,
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September, 1918. O 483

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APPOINTMENT OF TECHNICAL OFFICER.

The Committee (which is

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THE WHIRLING SPEED OF SHAFTS SUPPORTED IN THREE BEARINGS.

By Arthur Morley.

Section 1. *Introduction.*—When the rotary inertia of a shaft and its loads are negligible it is well known that the calculation of the whirling speed corresponds exactly to that of the frequency of transverse vibrations, and when the rotary inertia is known but small, a simple correction can be made to allow for it.

Such calculations have been made the subject of papers by Greenhill,* Dunkerley,† Chree,‡ and others.§

For relatively light shafts carrying heavy loads which control the critical speed, it is usual to assume the form of the deflection curve of the axis of the shaft during whirling or vibration, giving an ordinate of the curve an arbitrary magnitude. From such an assumption it is possible to write an equation of the strain energy of the shaft in its most deflected position, to the kinetic energy of the vibrating shaft in passing through its mean or undeflected position, or to the increase of kinetic energy of the rotating shaft due to its deflection during whirling.

It is usual further to assume as a deflection curve, under the action of the centrifugal force of the loads (or the inertia of the loads in transverse vibration) the form corresponding to the deflection of the shaft from a horizontal position under the action of gravitation upon the loads. In the case of shafts continuous through three or more bearings which divide the shafts into two or more spans, it it usual to assume such a curve as would be produced by hypothetical gravitational forces proportional to the loads and perpendicular to the axis of the shafts, but oppositely directed in successive spans.

The justification for such assumptions, as the basis of calculation, is the principle used by Rayleigh,¶ that the frequencies so calculated are not greatly affected by considerable differences in the assumed form of deflection. Nevertheless the accuracy of the calculation is to some extent affected by the validity of the assumed form of deflection. And for all forms other than the true one the result of the calculation of speed or frequency will be above the true value.

In the case of a shaft simply supported at its two ends, the form taken by the axis under (*e.g.*, gravitational) forces, simply proportional to the masses of the loads, does not greatly differ from the form taken under the centrifugal forces, which are actually proportional not only to the mass of the loads but to the (deflected) distance of their centres of mass from the axis of rotation.

It is possible in any case to obtain successive approximations to the true critical speed, the great part of the gap between the first approximation and the true or limiting value being bridged at the second approximation. In the case of the shaft simply supported at its ends the correction of the first approximation is generally exceedingly small (say, less than 0·1 per cent.) for the reason just stated, that the true and assumed forms of deflection do not greatly differ. But it is not safe to suppose that the same is true in other circumstances.

It is proposed to show that in the case of a shaft supported in three bearings the correction to be made is much greater; also that, *e.g.*, Dunkerley's well-known empirical rule for calculating the frequency or whirling speed of a shaft carrying more than one load is considerably in error when applied to such cases.

Where the calculation of whirling speed is of practical importance, as in turbo-alternators and turbo-blowers, it is usual to find that the shaft is not of constant diameter, but varies considerably and generally discontinuously or almost so. Algebraic expressions for deflection such as were used by Dunkerley and Chree then become very cumbersome, if not impossible, and it is necessary to resort to graphical or tabular methods of calculation. But for the purpose of illustrating the calculation of whirling speeds by successive approximation and comparisons with other approximate methods of calculation, simple cases susceptible to algebraic treatment will also be convenient.

Section 2. *General Notation.*—

E = Young's modulus for the material of the shaft.
I = moment of inertia of the area of section of the shaft = $d^4/64$.
l = length of the shaft.
y = amplitude of vibration or whirl at a distance x along the shaft from the origin.
ω = angular velocity of the shaft = $2\pi n = \pi N/30$.

where

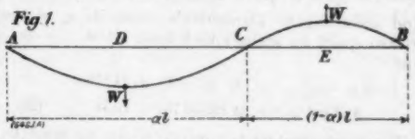
N = revolutions per minute.
n = revolution per second.

Section 3. *The Calculation from the Equation of Energy.*—If the shaft has a number of loads such as W_1, W_2, W_3—including, if appreciable, the shaft itself, each producing centrifugal forces P_1, P_2, P_3—&c., respectively, then equating the kinetic energy to the strain energy, both resulting from the deflection, during whirling of arbitrary magnitude

$$\left.\begin{aligned} \frac{\omega^2}{2g}\Sigma\,(W_1 y_1^2 + W_2 y_2^2 + W_3 y_3^2 + \ . \ . \ .) \\ = \tfrac{1}{2}\Sigma\,(P_1 y_1 + P_2 y_2 + P_3 y_3 + \ . \ . \ .) \\ \text{or } \omega^2 = \frac{g\,\Sigma\,(P\,y)}{\Sigma\,(W\,y^2)} = \frac{g}{y_m} \end{aligned}\right\} \quad (1)$$

This is true whatever the form of y, for if we write $P_1 = W_1\omega^2 y_1/g$, &c., the equation becomes an identity, if y is the actual deflection. But for an arbitrarily assumed form y' of y it will in general

Fig 1.



be an approximation justified by Rayleigh's principle. If it is assumed that y has the values y' proportional to those produced by gravitation on a horizontal shaft, the equation becomes,

$$\omega'^2 = g\,\Sigma\,(W y')/\Sigma\,(W y'^2) = g/y'_m \quad . \quad . \quad (2)$$

where $y'_m = \Sigma\,(W y'^2)/\Sigma\,(W y')$, a "mean value" of the deflections y', and is a first approximation to the value y_m in equation (1), and ω' is a first approximation to the value ω.

Loads distributed at a rate w per unit length of shaft may, if appreciable, be dealt with by including $\int w\,y'\,dx$ and $\int w\,y'^2\,dx$ in $\Sigma\,(W y')$ and $\Sigma\,(W y'^2)$ respectively.

Section 4. *The Method of Successive Approximation.*—Stodola ("The Steam Turbine," second edition, Article 48) has described a method of successive approximation which consists in assuming a form y' of deflection and a value of ω, say ω', calculating the centrifugal forces P, and from these deducing the form (y'') of a second deflection curve, the ordinates of which give a value of the critical speed, viz.:

$$\omega'' = \omega'\sqrt{y'/y''}.$$

Unless the value ω'' is the same at every point in the shaft the process must be repeated until no further change in the form of deflection curve appears and the approximations to ω are the same throughout the length of the shaft. Lasche ("Marine Steam Turbines") describes a practically identical method.

These methods involve an examination of the successive results for all values of x, or for a shaft of negligible mass, at every load.

The method about to be described gives directly successive approximations to ω and their nearness to the true limiting value may be judged by the rapidly diminishing differences. The approach is very rapid and the calculation of ω being based on an average value throughout the curve, successive differences are unimportant compared with individual differences in form which show themselves at some selected (loaded) points of the shaft.

A correction of the approximation represented by equation (2) may be obtained by substituting for the gravitational loads W, the centrifugal forces exerted by these loads when rotating at the angular velocity ω', and their centres of gravity deflected by the amounts y', and calculating the deflections y'', so produced. Thus a load W_1, produces a centrifugal force

$$\frac{W_1\,\omega'^2\,y'_1}{g} = W_1\frac{y'_1}{y'_m} = W'_1 \text{ say} \quad . \quad (3)$$

and under such a system of loads its corrected deflection is y_1''. Using the values from such a corrected deflection curve, equation (2) becomes:

$$\omega''^2 = \frac{g\,\Sigma\,(W' y'')}{\Sigma\,(W' y'^2)} = \frac{g}{y''_m} \quad . \quad . \quad (4)$$

which gives a second approximation ω'' to the true value ω. If this value differs too much from the first approximation ω' given by equation (2), it may be corrected by again repeating the process, but it is doubtful whether this will ever be necessary.

Section 5. *Application to Various Forms of Support.*—From equation (3) it is evident that for a system of loads the centres of gravity of which are equally deflected, $W' = W$ and consequently $y'' = y'$ and equation (4) gives a value of ω'' exactly equal to ω' from equation (2), and successive results will all be alike and correct whatever the form of support of the shaft.

(*a*) *Freely Supported Ends.*—If the shaft is simply supported by bearings at its ends, the actual form of deflection under the action of the centrifugal force of the loads, as previously stated, differs but little, or any distribution of loads, from that under the gravitational forces of the same loads. For example, in the case of a uniformly distributed load such as the weight of the shaft itself (say, w per unit length), the known critical speed is given by:

$$\omega^2 = \pi^4\,g\,EI/w\,l^4 = 97.41\,g\,EI/w\,l^4 \quad . \quad . \quad (5)$$

while the first approximation by the formula (2) is,

$$\omega'^2 = \frac{3{,}024}{31} \times \frac{g\,EI}{w\,l^4} = 97.55\,\frac{g\,EI}{w\,l^4} \quad . \quad . \quad (6)$$

showing an excess in ω' over ω of only 0·07 per cent. The distribution of the centrifugal forces (proportional to deflection) actually differs widely from that of the uniform load of gravity, but the form of deflection differs little; it is to be remembered that the form of deflection under even a load all concentrated midway between the supports does not differ greatly from that under a uniformly distributed load. The former is

$$y = y_c\{3\,x/l - 4\,(x/l)^3\} \quad . \quad . \quad . \quad (7)$$

and the latter is

$$y = y_c\,16/5\{(x/l)^4 - 2\,(x/l)^3 + x/l\} \quad . \quad (8)$$

while for the centrifugal load of a uniform shaft the form is

$$y = y_c \sin\,(x/l)\,\pi \quad . \quad . \quad . \quad (9)$$

Similarly the error involved in the approximation (2) is always exceedingly small for any system of loads if the shaft is simply supported at its ends.

(*b*) *Shaft Freely Supported at its Ends and at an Intermediate Point.*—In this case the fundamental or lowest critical speed is evidently reached when the shaft bends into deflection loops oppositely directed in the two spans into which the shaft is divided by the intermediate bearing.

If the two spans are unequal in length the deflections in the longer span will generally be on the average larger than in the small span and the centrifugal forces will differ from the assumed gravitational forces by being generally relatively larger in the longer span and relatively smaller in the shorter span. This distribution of load as compared to the hypothetical gravitational loading corresponds to an increase of deflections in the large span and a decrease of deflections in the small span, and this in turn corresponds to a smaller amount of strain energy compared to the kinetic energy, and therefore to a lower value of ω the critical speed. Hence formula (2) gives somewhat too high a value, and the value (4) shows a diminution.

For the purpose of illustration a round shaft A B (Fig. 1), of constant diameter, will be chosen, the length l being divided at a support C into two parts, $\alpha\,l$ and $(1-\alpha)l$, in the ratio $\alpha/(1-\alpha)$ one to the other, and carrying two equal loads W, one in the centre of each span at D and E. Assuming (gravitational) forces of W at D and — W at E, the simple theory of flexure gives

$$\left.\begin{aligned} y'_D = k\,\alpha^2/128\,\{(16 - 9\,\alpha)\,\alpha + 9\,(1-\alpha)^2\} \\ = k\,(\alpha^2/128)\,(9 - 2\,\alpha) \end{aligned}\right\} \quad (10)$$

(Due to W at D) (Due to — W at E)

$$\left.\begin{aligned} y'_E = k\,(1-\alpha)^2/128\,\{-9\,\alpha^2 - (1-\alpha)\,(7 + 9\alpha)\} \\ = (k\,(1-\alpha)^2/128)\,.\,(7 + 2\,\alpha) \end{aligned}\right\} \quad (11)$$

(Due to W at D) (Due to — W at E)

* Proc. Inst. M.E. 1883.
† Phil. Trans. Roy. Soc. 1894. Vol. A.
‡ Phil. Mag. 1904.
§ The writer, Engineering, July 30 and August 13, 1900. Kerr, Engineering, February and March, 1916. Webb, Engineering, November 2, 9, and 16, 1917.
¶ "Theory of Sound," vol. I, Arts. 182, 183, &c.

where $k = W l^3/6 E I$. Substitution of these values in equation (2) gives the value of ω', the first approximation to ω. But to avoid algebraic complexity in proceeding to a second approximation a numerical case will be considered, viz., $a = 2/3$, or spans in the ratio of 2 to 1.

Substituting in (10) and (11) the deflections are :

$6^4 y'$ ...	Due to W at D.	Due to − W at E.	Total.
$6^4 y'_D$ ...	$30\,k$	$4{\cdot}5\,k$	$34.5\,k$
$6^4 y'_E$ ...	$-\,4.5\,k$	$-\,4.875\,k$	$-9.375\,k$

Hence from equation (2) :

$$\omega'^2 = \frac{6^4 \cdot g}{k} \frac{34.5 + 9.375}{(34{\cdot}5)^2 + (9.375)^2} = \frac{6^4 \cdot g}{k} \times \frac{1}{29.128} \quad \text{or } y'_m = \frac{29.128\,k}{6^4} \qquad (11A)$$

Proceeding to a second approximation, the approximate centrifugal forces are by (3) :

$$\text{at D,} \qquad W'_D = W \cdot \frac{34.5}{29.128} = 1.184\,W \quad . \quad (11B)$$

$$\text{at E,} \qquad W'_E = -\,W \cdot \frac{9.375}{29.128} = -\,0.3218\,W \quad . \quad (11C)$$

The resultant deflections produced by these loads will be :

$$6^4 y'' = (30 \times 1.184)\,k + (4.5 \times 0.3218)\,k = 36.97\,k$$

$$6^4 y'' = -\,(4.5 \times 1.184)\,k - (4.875 \times 0.3218)\,k = -\,6.90\,k$$

Hence from equation (4) :

$$(\omega'')^2 = \frac{6^4 g}{k} \frac{(36.97 \times 1.184) + (6.90 \times 0.3218)}{(36.97)^2 + (6.90)^2} = \frac{6^4 g}{k} \cdot \frac{1}{30.761} \qquad (13)$$

Dividing (11A) by (13),

$$\frac{\omega''}{\omega'} = \sqrt{\frac{29.128}{30.761}} = \sqrt{\frac{1}{1.056}} = \frac{1}{1.028} \quad . \quad . \quad (14)$$

i.e., ω'' is about 2·8 per cent. lower than ω'.

Repeating the process gives :

$$W''_D = (36.97/30.76)\,W = 1.202\,W \quad . \quad . \quad (15)$$

$$W''_E = -\,6.90/30.76)\,W = -\,0.2243\,W \quad . \quad (16)$$

$$6^4 \cdot y''_D = (30 \times 1.202)\,k + (4.5 \times 0.2243)\,k = 37.07\,k$$

$$6^4 \cdot y''_E = -\,(4.5 \times 1.202)\,k - (4.875 \times 0.2243)\,k = 6.503\,k$$

$$(\omega''')^2 = \frac{6^4 g}{k} \frac{(37.07 \times 1.202) + (6.50 \times 0.2243)}{(37.07) + (6.50)} = \frac{6^4 g}{k} \times \frac{1}{30.782} \qquad (17)$$

Hence :

$$\frac{\omega'''}{\omega''} = \sqrt{\frac{30761}{30782}} = \sqrt{\frac{1}{1.0007}} = \frac{1}{1.00035} \quad . \quad (18)$$

or ω''' is only 0·035 per cent. lower than ω'' and subsequent corrections are negligible. The second approximation is substantially equal to the limit ω.

Similar computations have been made for other ratios of the lengths of the two spans into which the shaft is divided by the bearing at C. The results are set forth in Table I.

For all ratios of the two spans ω' is too high, but the excess is not great and never amounts to 3 per cent. The values of $\left(\frac{\omega'}{\omega''}\right)^2$ are shown in Fig. 2, and also in Fig. 3.

Section 6. *Dunkerley's Empirical Rule.*—Dunkerley's well-known empirical rule may be tested for the three bearing support by the results of the preceding section. If ω_1 is the critical speed when the shaft carries only the load W at D and ω_2 that when it carries only the load W at E :

$$\omega_1^2 = 128\,g/k\,a^3\,(16 - 9\,a) \quad . \quad . \quad (19)$$

$$\omega_2^2 = 128\,g/k\,(1 - a)^3\,(7 + 2\,a) \quad . \quad (20)$$

Fig. 2.

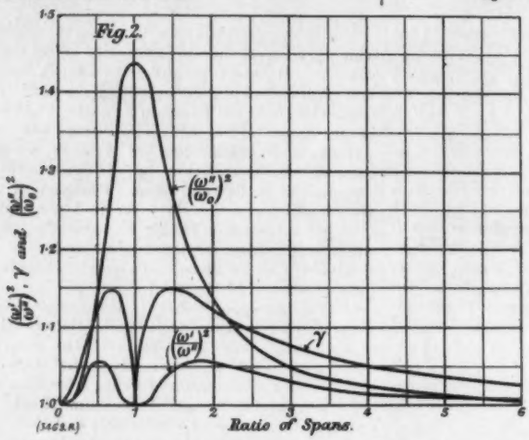
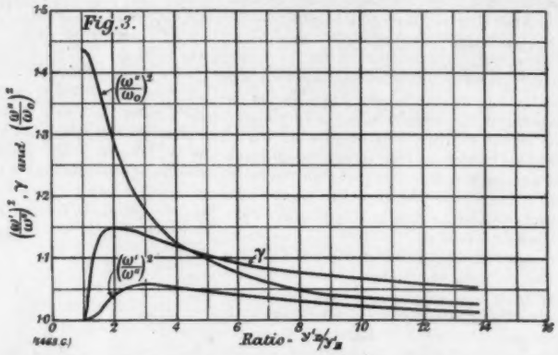


Fig. 3.



Or taking again the value = 2/3, i.e., a ratio of spans of 2 to 1 :

$$\omega_1^2 = 6^4 \cdot g/30\,k \qquad \omega_2^2 = 6^4 \cdot g/4.875\,k$$

And according to Dunkerley's rule, if ω_0 is the critical speed for a shaft with both loads : And :

$$1/\omega_0^2 = 1/\omega_1^2 + 1/\omega_2^2 \text{ or } \omega_0^2 = 6^4\ g/34.875\,k \quad . \quad (21)$$

$$\text{And } (\omega''/\omega_0)^2 = 34.875/30.761 = 1.134 \quad . \quad (22)$$

The corresponding factors by which ω_0 must be multiplied to give ω'' for various ratios of the spans, are given in Table II and are plotted in Figs. 2 and 3. It is evident that for this loading unless the spans are very unequal, Dunkerley's rule for this type of support needs considerable correction.

Table I.—(*For Two Equal Central Loads*).

(1)	(2)	(3)	(4)	(5)	(6)	(7)
a	Ratio of Spans $\frac{a}{1-a}$	$-\frac{y'_D}{y'_E}$	$\omega'^2 \times \frac{W l^3}{g E I}$	$\omega''^2 \times \frac{W l^3}{g E I}$	$\left(\frac{\omega'}{\omega''}\right)^2$	$\frac{\omega'}{\omega''}$
1/2	1·0	1·0	384·0	384·0	1·0	1·0
5/9	1·25	1·520	364·8	350·0	1·015	1·007
4/7	1·3	1·716	354·0	342·2	1·029	1·014
3/5	1·5	2·140	329·3	314·0	1·048	1·024
5/8	1·6	2·610	305·8	289·8	1·055	1·027
0·64	1·7	2·944	292·0	275·9	1·058	1·029
2/3	2·0	3·680	256·9	252·8	1·056	1·028
3/4	3·0	7·94	201·7	195·6	1·0305	1·015
4/5	4·0	13·76	173·0	170·5	1·0144	1·007
1	∞	∞	109·7	109·7	1·000	1·000

Table II.—(*For Two Equal Central Loads*).

(1)	(2)	(3)	(4)
a	$\frac{a}{1-a}$	$\left(\frac{\omega'}{\omega''}\right)^2$ or $\frac{y'_D}{y''_m}$	$\left(\frac{\omega''}{\omega_0}\right)^2$
1/2	1·0	1·000	1·4375
5/9	1·25	1·138	1·373
4/7	1·3	1·149	1·334
3/5	1·5	1·1475	1·248
5/8	1·6	1·143	1·208
0·64	1·7	1·136	1·179
2/3	2·0	1·122	1·134
3/4	3·0	1·076	1·047
4/5	4·0	1·05	1·0252
1	∞	1·000	1·000

Section 7. *Baumann's Method.*—Baumann* has suggested that for practical cases the equation for ω being of the form

$$\omega^2 = (g/y) \times \text{constant} \quad . \quad . \quad . \quad (23)$$

the critical speed may be found approximately for practical purposes by writing, say,

$$\omega^2_n = \gamma\,(g/y'_{max.}) \quad . \quad . \quad . \quad (24)$$

where $y'_{max.}$ is the maximum deflection under the hypothetical gravitational forces and γ is a coefficient which it is suggested does not in practical cases of turbo-electric machinery differ greatly from 1·07 or 1·08

For the loading chosen to illustrate Sections 4, 5 and 6, it may be interesting to note how this coefficient γ varies, for $y_{max.}$ is equal to y'_D, so that :

$$(\omega''/\omega_n)^2 = y_D'/y''_m \quad . \quad . \quad . \quad (25)$$

These ratios are given in Column 3 of Table II, and are shown plotted on Fig. 2. All the ratios shown in Fig. 2 are also plotted in Fig. 3 with the ratios of the (gravitational) deflections of the two loads as abscissæ, this being probably a better basis for correction of other practical examples of loaded shafts.

(*To be continued.*)

* "Recent Developments in Steam Turbine Practice." Journal Proc. Inst. E.E., 1912, Part 213, vol. xlviii.

STATE ELECTRICITY, ELECTRICITY SUPPLY COMBINES, &c.

(*Concluded from page* 549.)

In the southern part of Sweden the State owns water power which, after regulation of the rivers and lakes concerned, and with the water power practically exploited to the full, amounts to—

K.w.h. per Annum.	
1,200,000,000	in the Göta River.
300,000,000	in the Dala River.
100,000,000	in the Motala River.
20,000,000	in the Ljusnan.
100,000,000	in the Lagan.
1,720,000,000	k.w.h. per annum.

The above total comprises the water power acquired for the electrification of the State railways. For the current year the aggregate load for the part of the country in question will probably amount to 720,000,000 k.w.h., or about 40 per cent. of the available power. Of the above 720,000,000 k.w.h. about 400,000,000 k.w.h. are disposed of for electro-chemical industries, but these may in the future to a great extent have to make room for electro-mechanical industries, when the exceptional tariffs for the former expire, in which case much electro-chemical industry is likely to be transferred further north. The State, however, does not possess any waterfalls of importance north of the Dala River until Lapland is reached.

According to the last official report there were in Sweden, in 1916, 591 electric power stations, of which the aggregate power was 603,664 kw. Of this, again, 490,824 kw. were in hydro-electric stations, and the balance, 112,840 kw., in stations worked by steam or other power. The aggregate length of distribution lines of more than 250 volts pressure to earth amounted to 11,770 km. The largest aggregate of power is found in the Alosberg district (län) with 73,685 kw.; Uppsala district comes next with 72,035 kw. and Kopparberg district is third with 71,874 kw. Västernorrland has 53,133 kw. and Norrbotten 48,087 kw. The only district without any electric power station is that of the island of Gothland.

The different years vary very materially as regards the amount of work undertaken for the exploitation of waterfalls. The largest figures as regards private (and municipal) installations of this description were for the year 1907, when they approached 90,000 turbine horse-power, whilst for the years 1910 and 1911 they fell below 10,000 turbine horse-power. Since then, there has, however, been an increase, and for 1916 the figure was 51,000 h.p. Various

restrictions and legal proceedings have, no doubt, impeded a more rapid development, but improvement is evidently about to set in.

The problem of a more comprehensive electrification of the rural districts is in Sweden, as in Norway, attracting much attention, and two experts have investigated the matter and just presented a report. The area so far electrified amounts to 235,524 hectares (1 hectare equals 2·47 acres), and the distribution lines in question have an aggregate length of 7,165 km., while the cost of the installations and works concerned comes out at about 12,000,000 kroner (666,000*l.*). The total area of cultivated soil in Sweden amounts to about 3,700,000 hectares (9,300,000 acres), and the cost of electrifying this area, according to the above average of about 30 kroner per hectare (13s. 6d. per acre), would thus amount to some 110,000,000 kroner. As this aggregate of land, however, comprises districts where the above average of cost will be materially exceeded, and the calculations are based upon prices as they were before the war, it goes without saying, that the sum of 110,000,000 kroner would have to be very considerably augmented, doubled perhaps, or more. The report, based upon the existing installations, holds that it is financially practical to electrify districts where the cultivated area exceeds 30 per cent. of the total area, and about 50 per cent. of the country's cultivated area is reckoned to comply with this condition. Putting the cost at 40 kroner per hectare (18s. per acre) which would seem a low figure at present, the cost would amount to some 75,000,000 kroner (4,170,000*l.*). There can be no doubt that the farmers more and more realise the practical value of electric energy; the experts recommend the establishment of a State loan fund for this purpose.

In the mining and industrial district of Central Sweden (Gergslagen) efforts have for some time been to bring about an electric power station combine, and the Bergslagen's Power Board has now been formed for portions of the district. The electric power stations of the central district of Sweden in question lend themselves satisfactorily to the scheme of co-operation, only short connecting lines being needed. Within the Bergslagen district the 50 periods three-phase system is prevalent, the Gränges berg and Kopporberg power stations work with 60 periods and the Ludvika installations with 40 periods. As regards the Bergslagen proper, that is the area within the rivers Svartälven, Arbogaaon, Hedströmmen and Kolbäcksan, a combination of all the 50-period power stations of this district would only entail an expenditure of 1,000,000 kroner (55,555*l.*) and make it possible to increase the annual production of primary energy by about 20,000,000 k.w.h. With the requisite steam reserves an additional 40,000,000 k.w.h. could be generated per annum, which would make the entire distribution independent of shortage of water. These 60,000,000 k.w.h. gained through the combine represent an addition in the production of energy of about 40 per cent.; they will entail a cost of about 1 öre (0·13*d.*) per kilowatt-hour, which is considerably less, only about one-half, of the average cost of energy production in the Bergslagen district at present. The combine scheme has been supported from an early stage of the negotiations by some 30 to 40 power station concerns, with more than 100 power stations. These have about 85,000 turbine horse-power and 26,000 h.p. from steam or other motors, and the combine movements extends to the Gestrikland district and southern Dalicarlia.

With regard to the business or financial structure of the combine the leading principle has been not to interfere too much with the independence of the individual concerns. The combine installs the lines necessary for co-operation, beyond those already existing, at its own cost, and the necessary capital is obtained by contributions from its members, whereas the latter themselves look after any necessary alterations within their own system, as well as transformers needed for connection with the lines of the combine. The combine places at the disposal of its members the energy they require and apply for, buying the energy from other members, who have any to spare, or by purchase from outside power stations.

The question of settling the price for energy supplied of course presented some difficulties, and involved classification. Primary power is regarded as the power available throughout the year, day and night, and secondary power as the power available with a fairly ample volume of water. Power incidentally available, be it from a temporary smaller requirement of energy on the part of the member in question, or from incidental surplus of water power, is called surplus power. Finally, power generated by steam or other heat plant is called reserve power. On the other hand, power supplied beyond the contracted quantity is called top power and the power which under certain circumstances is derived from stored water is called stored power. With reference to the margin which the combine naturally requires between the buying and the selling price, this has, for primary power, been fixed at 15 kroner per kilowatt and ½ öre (0·065*d.*) per kilowatt-hour. It is evident that concerns in a position to dispose of power favour a high price, and those in need of energy the reverse, but the future trend is likely to show a decrease in the sale of energy to the combine and an increase in the purchase. It is therefore expedient that the combine shall be enabled to handle energy at reasonably low figures (some may have to be drawn from North Sweden), although the combine must, of course, be on the safe side. The price for primary power has therefore been fixed at 15 kroner per kilowatt per year and 1 öre (0·13*d.*) per kilowatt-hour, which is somewhat below what may be called the current price for primary power in the Bergslagen district, whilst the vendors of primary power obtain 60 kroner per kilowatt per year and ½ öre per kilowatt-hour, measured at the high-voltage side of the member's transformer station. The selling price to members for surplus power has in the meantime been fixed at 1 öre per kilowatt-hour. The price for reserve power purchased by the combine from its members has been fixed at 20 kroner per kilowatt hour per year, plus the member's own cost for fuel, increased by 20 per cent. if the power is guaranteed available at the request of the combine. The members are entitled to buy reserve power from the combine at a price of 30 kroner per kilowatt and 2·5 öre per kilowatt-hour, at normal coal prices, with an addition of 0·6 öre per kilowatt-hour for each rise of 5 kron r in the price for coal. The price for top power has in the meantime been put at 10 öre per kilowatt-hour, but not less than double the kilowatt-hour price for reserve power.

It has often been suggested that, as compared with Sweden, the Norwegian State has been taking the matter of exploiting its water falls rather easily. Surprise has more especially been expressed in connection with the powerful and well located Nore Falls. But these falls were purchased some ten years ago, and the plans now prepared for their exploitation are on large lines. They comprise installations with a capacity of 368,750 turbine horse-power, which formidable capacity can be further increased to about 460,000 turbine horse-power. We propose, however, to deal with this large undertaking in a separate article. The problem of what may be called a national system of electric energy supply is at present attracting much attention in Norway, but opinions seem to diverge considerably on this point.

The Norwegian State is apparently about to embark upon a more active policy in the field of electric energy production. Not only have the Government bought some additional falls, the Skjörnfossen, Foseen, and the Formofossen, Grong, but in addition to the vast undertaking of exploiting the Nore Falls, it is being urged to exploit the Kvina water power, through the medium of special committees appointed by local authorities, and, what is of more immediate interest, it has decided to purchase the Glomfjord concern, that is, the large hydro-electric power station now in course of construction at Fykanaaga, Melöy. Through additional regulation of the Storglaanes water the capacity of this power station can be increased from 45,000 h.p. for which the power station, now being built, is calculated, to 80,000 h.p. The Government is in a strong position in this deal, inasmuch as the concession according to which the company has undertaken the laying-out of the power station in question, does not provide for any additional enlargement, although a considerable amount of preparatory work, tunnels, &c., for the extension already has been undertaken. Under the circumstances an outlay of some 6,000,000 kroner is considered sufficient for the completion of the second stage with its additional 35,000 h.p., a device which reduces the aggregate cost of the completed installation to the very moderate average of 38 kroner (42*s.*) per horse-power. An annual net surplus of fully 2,500,000 kroner is reckoned upon after paying 5 per cent., besides 700,000 kroner for taxes. Already contracts have been made which, from July 1 next year, will pay interest and 2 per cent. amortisation on the purchase money, and leave a small surplus.

A number of Norwegian towns have also purchased waterfalls, as will appear from the subjoined table, which, however, is not complete :—

	Capacity of Waterfalls when fully Utilised. Kw.
Christiania	112,000
Bergen	22,000
Drontheim	54,000
Stavanger	100,000–150,000
Christiansand...	90,000
Haugesund	40,000
Lillehammer	9,000
Porsgrund, jointly with Solum and Gjerpen rural municipalities ...	25,000

In addition, the city of Christiania has obtained over 20,000 kw. from the Kykkelsrud concern. Other towns which have been unable to purchase water power owing to all suitable falls already having been taken up, have covered their requirements by contracts extending over considerable periods. This more especially refers to the towns on either side of the Christiania Fjord, the larger waterfalls in this part of the country having been bought at a comparatively early date, or secured by large private power concerns, such as the hydro-electric power stations at Kykkelsrud, Vamma and Hafslund on the east side of the firth, and the Skollenborg and the Frerchow-Fritzöe power stations on the west side. At least eight towns have entirely discarded their steam or gas electric stations and secured water power. In Christiania and Bergen the steam stations have been maintained as a reserve. Half a dozen towns still confine themselves to steam, gas or Diesel motors for generating their requirements of electricity, a few have been obliged or found it expedient to construct steam or Diesel motor stations as a supplement to their hydro-electric power stations, but the remaining 50 town electricity works in Norway use exclusively water power, and their number is likely to increase. Alternate current, 50 periods, is used in almost all towns.

Apart from the municipal power stations the following table refers to a dozen large private undertakings which together with the above represent, or represented when made up in 1918 (but it is the last available), about 80 per cent. of all electric power stations in the country :—

Country.	Kw.	Application.
Kykkelsrud ...	31,000	Electricity supply— carbide and other big industries.
Vamma ...	27,000	
Hafslund ...	17,000	
Hollenborg ...	4,000	Electricity supply and wood pulp industry.
Treschow-Fritzöe	10,000	
Boilefos ...	24,000	Electrometallurgical industry.
Lienfos ...	14,000	Nitrate industry.
Svälgfos ...	42.000	
Rjukan I ...	110,000	
Rjukan II ...	114,000	
Tysso ...	90,000	Carbide and other electrometallurgical industry.
Meraker Bruk...	11,000	

All these private undertakings have alternate three-phase current, 50 periods, except Tysso and Boilefos, which use 25 periods.

It is more especially during the last six to seven years that the exploitation of Norway's water power has been accelerated; in the beginning of 1911 the aggregate generator capacity amounted to some 240,000 kw., which figure during the next five years or so swelled to 670,000 kw. The amount of water power exploited already exceeded 1,000,000 h.p. a year ago, and if the curve should continue

to rise at the same rate as it has done since 1907, some 6,000,000 h.p. will have been exploited in the course of the next fifty years. That this amount of water power is available in Norway is absolutely certain.

This wealth of water power on the part of Norway has within the last few weeks prompted an inter-Scandinavian combination or co-operation, in which Denmark will be the recipient of electric energy. Some 200,000 h.p. have so far been mentioned, generated principally, if not entirely, in Norway and transmitted partly by submarine cable.

EXPRESS LOCOMOTIVES FOR 3-FT. 6-IN. GAUGE.

The line of the New Zealand Government Railways between Christchurch and Timaru (see Fig. 1) is the easiest stretch of 100 miles in the Dominion of New Zealand, being straight and almost level for nearly the whole distance, but the express trains frequently involve loads of over 400 tons behind the tender, while the prevalent north-west gales make flange resistance heavy. The scheduled time for express trains on this 100-mile run is 2 hours and 58 minutes with five stops totalling 10 minutes, and allowing 2 minutes for time lost during acceleration period for each start and stop; this gives an average running speed of 38 m.p.h. These trains were formerly worked by four-cylinder balanced, compound locomotives of the Pacific type (Fig. 2), having 12-in. and 19-in. cylinders, 22-in. stroke, 54-in. driving wheels, and using saturated steam at 225 lb. working pressure. These engines weigh about 47 tons, of which 30 tons are available for adhesion, and with steam at 80 per cent. of the boiler pressure they develop a tractive force of 16,900 lb. (computed by the rational formula for compounds)

$$T = \frac{0{\cdot}8\ pe\ (2\,H^3 - H^4/L^3)}{D}\ *$$

They are able to handle the average train of 14 carriages (280 tons) on a coal and water consumption of 44 lb. and 35 gallons per mile. For loads above this they are under-cylindered, so Mr. H. H. Jackson, chief mechanical engineer, designed for this service some non-compound engines of the Pacific type fitted with superheaters of about the same weight as the compounds, which were built in the New Zealand Railway workshops at Addington.

The New Zealand Government Railways are of 3-ft. 6-in. gauge, and the track restrictions in force allow only 10 tons axle load and a maximum speed of only 50 m.p.h., while the loading gauge is only 8 ft. wide and 11 ft. 6 in. high, so the conditions are severe.

Superheated steam of 180 lb. pressure was decided on, with 54-in. coupled wheels, and 17-in. by 26-in. cylinders. Usually an adhesive factor of 4 is used for express work, but as the line is nearly level this was reduced to 3·6 in order to gain the full benefit from superheating by using large cylinders. A wide firebox was desired, so this entailed a trailing bogie, and a four-wheeled leading bogie was necessary to distribute the weight properly. The three-point system of equalisation is generally used for Pacific engines on the New Zealand Railways, so the driver springs are connected by equalising beams, with each other and with the trailing bogie, each side being a distinct system. Fig. 3 shows the preliminary sketch design prepared at this stage.

The narrow gauge makes outside cylinders compulsory, and a simple casting as possible is advisable in Colonial foundries. Figs. 4 to 7, Plate XLVI, show how this was obtained. Outside steam and exhaust pipes are used, and the main cores are everywhere circular in section united by the straight cores for the steam ports at each end. This absence of passages is especially desirable with superheated steam since it minimises expansion and contraction of the castings in service. Special care was taken to ensure metal of uniform thickness and to guard against shrinkage strains generally, while bushes were provided for the steam chest and cylinder wearing surfaces to allow softer and stronger metal to be used for the main castings.

A simple type (see Fig. 8) of combined drain cock and relief valve is fitted, worked by rods actuated by air pressure from the Westinghouse brake service. The course of the outside steam pipe is shown on the smoke-box drawing (see Figs. 25 and 26, Plate XLVI), and the exhaust pipes are led from each end of the steam chest into the central casting which supports the smoke-box (see Fig. 6). The steam-chest bushes are made as short as possible and the centre of each chest is made the same diameter as the bush (see Fig. 6), to give a straight run for the valve when being put in place. If this is not done the split packing rings fall into the centre space and catch on the edges of the bush, causing trouble.

Four-feed mechanical lubricators were fitted to the first 10 engines, but an American type of sight-feed lubricator is now being used. This gives a more flexible feed, which is desirable now that the engines are running in various services with widely different conditions of grade and speed. The oil is led from one feed into an atomiser and check valve on the steam pipe and another feed goes to the check valve on the steam chest. No drifting valve is used, but a saturated steam valve in the cab allows a slight flow of "wet" steam to pass into the steam pipe just above the atomiser. This entirely prevents the annoying deposit of "carbonised" oil which gums up the valve rings and bushes on superheated engines of other classes not fitted with this valve. It is peculiar that the drivers who make the most use of this device show the best results in coal and water consumption, but the valve is only 1 in. diameter and is only opened very slightly. The drivers were, at first, supposed to open it only when drifting, but now many drivers leave it open from shed to shed, holding the train when necessary by the tender hand brake. The temperature of the superheated steam averages about 700 deg. F. in express running, but the lubrication is now entirely satisfactory.

The piston valves are 9½ in. diameter and have no tail rods. The weight of each valve, 100 lb., is not carried by the spindle but on wearing strips (see Fig. 9), 5½ in. by 2½ in., on the bottom of the valve The strips run on the bush, and thus cover the split in the packing rings and also ensure that the unbalanced steam pressure on the valves falls only on a 5½-in. chord, and not on the whole diameter of the valve. The packing rings are kept narrow, ¼ in. by ¼ in., in order to minimise the steam load between them and the bush. At 180 lb. pressure the maximum total unbalanced steam load on this valve is about 5 tons.* The bridges are carried diagonally across the port to equalise wear (see Fig. 12) and are as wide apart, 1⅛ in., as has been found advisable in practice. The splits in the rings are also diagonal, and are kept ⅛ in. apart when fitted, to guard against the expansion due to superheated steam, which causes the rings to seize if this detail is not attended to. Inside admission is used

Fig. 1. DIAGRAM OF GRADES BETWEEN CHRISTCHURCH & TIMARU SHEWING EXPRESS STOPS.

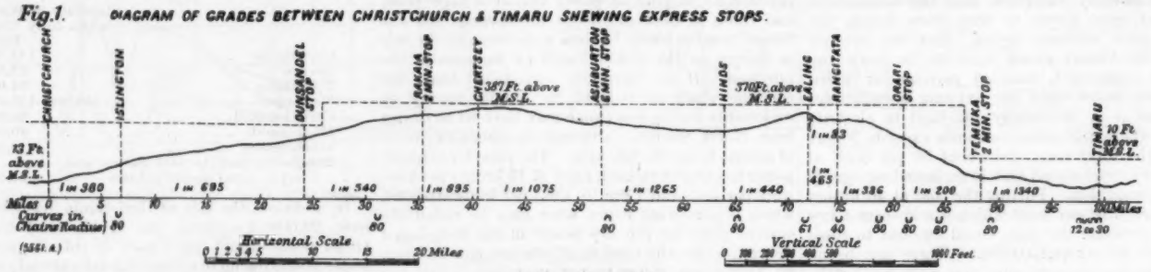
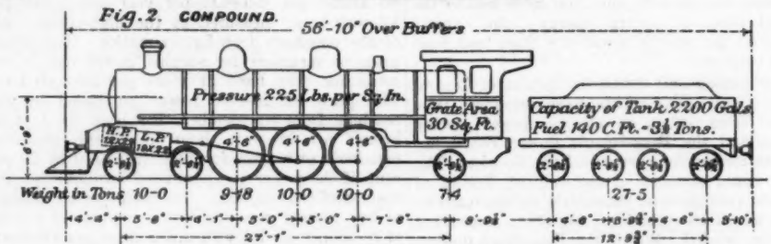
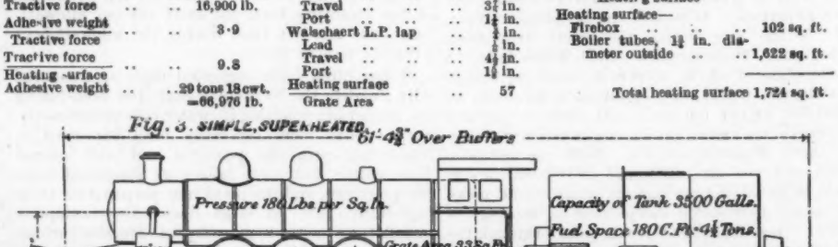


Fig. 2. COMPOUND.


56'-10" Over Buffers
Pressure 225 Lbs. per Sq. In.
Grate Area 30 Sq. Ft.
Capacity of Tank 2200 Gals.
Fuel 140 C. Ft. - 3½ Tons.
Weight in Tons 10-0 9-18 10-0 10-0 7-4 27-5
27'-1"
48'-8"

Engine and tender in working trim	74 ton 7 cwt.	Walschaert H.P. lap	¾ in.	Tractive force × dia. drivers / Heating surface	529
Tractive force	16,900 lb.	Lead	⅛ in.		
Adhesive weight / Tractive force	3·9	Travel	3⅝ in.	Heating surface—	
		Port	1½ in.	Firebox	102 sq. ft.
Tractive force / Heating surface	9.8	Walschaert L.P. lap	¾ in.	Boiler tubes, 1⅝ in. diameter outside	1,622 sq. ft.
		Lead	⅛ in.		
Adhesive weight	29 tons 18 cwt. = 66,976 lb.	Travel	4½ in.		
		Port	1½ in.		
		Heating surface / Grate Area	57	Total heating surface	1,724 sq. ft.

Fig. 3. SIMPLE, SUPERHEATED.


61'-4¾" Over Buffers
Pressure 180 Lbs per Sq. In.
Grate Area 33 Sq. Ft.
Capacity of Tank 3500 Gallons
Fuel Space 180 C. Ft. - 4½ Tons.
Weight in Tons 9-2 10-0 10-8 9-19 7-11 32 Tons
27'-1"
10'-8"
14'-9"
51'-6" Total Wheelbase

Engine and tender in working trim	79 tons	Walschaert gear, lap	1 in.	Heating surface—	
Tractive force	20,000 lb.	Lead	⅛ in.	Firebox	123 sq. ft.
Adhesive weight	30 tons 7 cwt. = 67,984 lb.	Full travel	4⅝ in.	Boiler tubes, 1⅝ in. diameter outside	772 sq. ft.
		Port	1⅝ in.	Superheater flues	250 sq. ft.
Adhesive weight / Tractive force	3·4	Heating surface / Grate area	50	Superheating surface × 2	480 sq. ft.
Tractive force / Heating surface	12·3	Tractive force × dia. drivers / Heating surface	685	Total heating surface	1,625 sq. ft.

* i.e., Equivalent cylinder diameter for 4 cyl. compounds

$$= \sqrt{2\,H^3 - \frac{H^4}{L^3}},$$

when H = the diameter of the high pressure and L that of the low-pressure cylinders.

* Steam pressure (180) × {Area of 3 rings + 1 wearing strip) + Exhaust pressure (40) × {Area of 1 ring + 1 wearing strip} = 5 tons nearly.

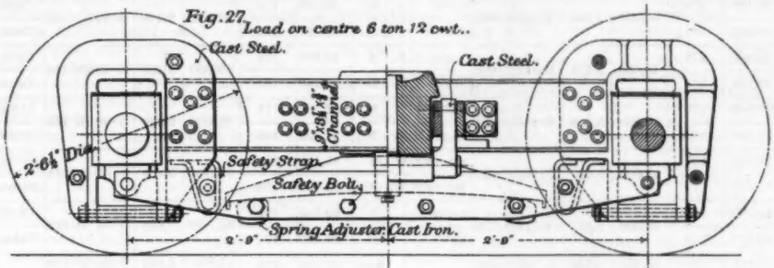
and the only packing required on the valve spindle is afforded by lea ve grooves in the guide (see Fig. 6).

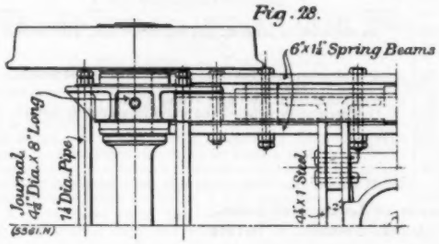
The Walschaert gear (see Figs. 13 and 14) is set to give ⅛ in. lead, and the lap of the valves being 1 in., a cut-off at 80 per cent. and release at 90 per cent. are given with a travel of 4⅜ in. in full gear. The position of the reversing shaft is chosen to give equal cut-offs, back and front, in running gear, and the slip is minimised (⅜ in. maximum) by finding a suitable position for the attachment of the eccentric rod to the link. The whole gear is in one vertical plane from the return crank to the valve spindle. The correctness of the design is proved by the results, the steam consumption being very low and the running smooth and free from wear.

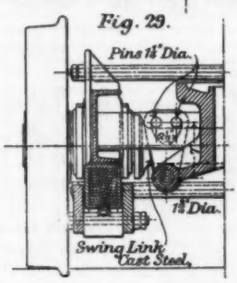
All the shell plates of the boiler (see Figs. 15 to 18) are ½ in. thick with the exception of the throat plate, which is ⅝ in. As the plate-rolls and riveting machine can take plates 10 ft. wide the boiler barrel is made in two courses. All the circumferential seams are single riveted. The longitudinal joint is on the top in each course and is made tight by acetone welding at each end. Neglecting this welding the joint has an efficiency of only 83 per cent., but it is a simple and very mechanical joint, and is especially designed for tightness. The tubes are kept well away from the barrel and clear of the radius of the tube plate. They are pitched in vertical rows, and spaced to encourage free circulation, and the result is a very free steaming boiler.

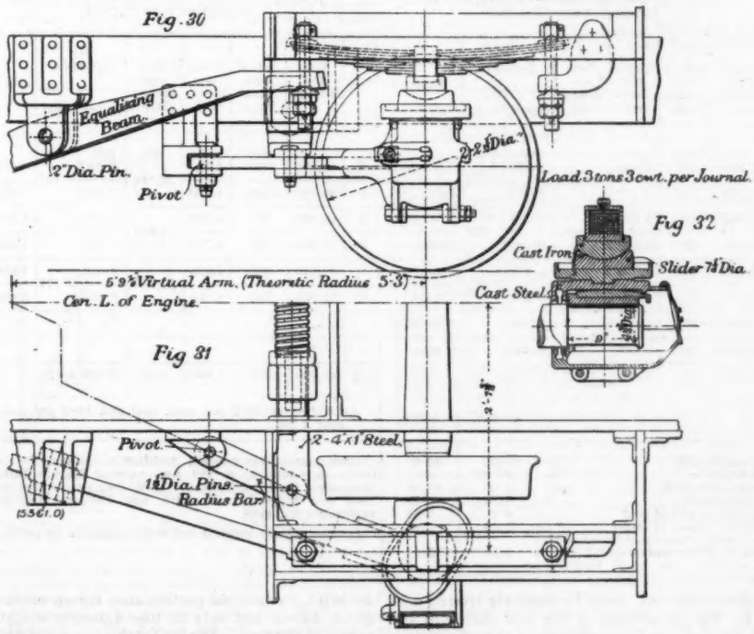
The fire-box is built of American fire-box steel, ⅜ in. thick, with a copper tubeplate 1 in. thick. This combination has proved very successful with iron tubes and after experience with all-steel and all-copper boxes this mixed type is now the standard. On the New Zealand Government lines the crown is stayed with radial stays throughout, the front seven rows being free to expand upwards. This arrangement gives a very clean crown, easily washed and inspected, with no tendency to gather scale and mud deposits. A splash plate is fitted just forward of the tubeplate to prevent the water surging off the crown when brakes are applied.

The New Zealand coals are highly bituminous and long flaming, so the fire-box is as deep as possible, with a long brick arch and a combustion chamber. Besides the advantage in promoting good combustion, the reduced temperature at the tube plate has practically abolished tube troubles and the boilers have run for over two years without the necessity of yet expanding any tubes in service. The foundation ring is a steel forging, 4 in. wide by 3½ in., double-riveted at the corners, but single-riveted elsewhere with the exception of an upper row at the same pitch as the side stays. This gives a thoroughly steamtight joint, and the upper row of rivets allows the bottom row of stays to be kept well above the ring, thus giving space for cleaning purposes. The mud plugs are brass, about 2 in. diameter, screwed to 12 threads per inch on a taper of 1 in 8, and are screwed direct into the plate. Special care was taken to have them properly placed, and the result is a very convenient boiler for wash-out purposes, and a boiler which is always as clean as possible.









purposes, and a boiler which is always as clean as possible.

The standard grate (see Figs. 19 to 24) consists of side dead plates, 2½ in. wide, with ½-in. bars and ⅞-in. spaces. These are made in five standard lengths (24 in., 27 in., 30 in., 33 in. and 36 in.) and fit all fire-boxes by varying the width of the front and back dead-plates between 2½ in. and 4 in. A drop door, 2 ft. wide by 18 in. long (see Figs. 20 and 21), is fitted in the grate under the firehole door, through which clinker and dirt can be dumped into ash pan. The ash pan is kept 3 in. below the mud ring all round to give plenty of air admission space, and this space is protected by covers of perforated plate. Shaking grates have not, proved satisfactory with the friable New Zealand coals, but the drop-door grate is a greatly appreciated convenience and renders the dumping and cleaning of fires a quick and easy job.

An extended smoke-box (see Figs. 25 and 26) is used, 55 in. diameter and 6 ft. long. No damper is used, but a deflector plate is fitted to prevent all the hot gases coming through the top flues. Although a steam temperature of 700 deg. is regularly reached no trouble has been experienced with the superheater tubes. The exhaust and chimney arrangements give very good results, although the nozzle is higher than the Schenectady experiments would warrant. However, the danger of grass and bush fires in New Zealand makes effective spark-arresting devices necessary, and the perforated spark-arresting plate fitted at the level of the exhaust may so alter conditions that the American results are not directly applicable.

The leading bogie (see Figs. 27 to 29, annexed), is of the swing-link type, with heart-shaped suspension links, and the wear of the driving wheel flanges has been so remarkably little that the angle of the swing links must be accepted as correct for this type and weight of engine. The bogie framing is formed of 9-in. channels which give a very rigid and cheap construction. The trailing bogie, Figs. 30 and 31, has outside axle-boxes (see Fig. 32), with large doors fixed on a large frame guided by radius bars, and the weight, which is equalised (or, rather, compensated) with the drivers, is taken on a slider between the axle-box and spring. In order to leave full space for the ash pan the radius bar is not swung on a central pivot between the frames but from a pivot on each side outside the frames (see Figs. 30 and 31). The bars converge to a point such that the virtual radius of bogie radial bar is $1\frac{1}{16}$ the theoretical length, and this point was determined by trial as giving satisfactory results. This radius was at first made three-quarters of that given by the formula, but proved too short. The axle-box brasses of both bogies are lined with a white metal mixture (lead 6, antimony 1) which has given excellent results. The conditions are fairly severe, particularly on the trailing bogie, where a 26½-in. wheel runs at regular speeds of 50 m.p.h., but ample bearing surface is provided.

The combination of outside cylinders on a 3-ft. 6-in. gauge so alters the relative value of the moments of the disturbing forces that neither the English (the minimum nosing moment method of D. K. Clark or Professor Dalby) nor American (two-thirds of the reciprocating weight placed opposite the crank) compromise, gives best results. In these engines that position of the counterbalance is chosen which gives the least hammer blow, and four-fifths of the reciprocating weight is balanced for fore-and-aft vibration while the nosing moment of all the reciprocating weight is entirely unbalanced. The running of the locomotive has proved entirely satisfactory at all speeds up to 60 m.p.h., and the nosing or boxing motion is quite negligible, in fact we are informed that it is doubtful if a steadier engine is running in the Dominion.

The reciprocating weights amount to 600 lb. per side, and 160 lb. are balanced in each coupled wheel, leaving

$$120 \text{ lb.} \left(\text{or } \frac{\text{Total weight of engine}}{880} \right) \text{ unbalanced per side.}$$

The "hammer-blow" or load variation amounts to 4,800 lb. per wheel at 54 m.p.h., or 43 per cent. of the static load. It will be remembered that an approach to this position of the balance weight has been tried by Mr. H. H. Vaughan on a Canadian Pacific locomotive, and while the unbalance of the nosing moment has been carried to a greater extent in this case it is satisfactory to record that nothing but good results have followed. The Tables on the next page show a comparison of the various compromises and give some data of the computations.

A tender of a modified Vanderbilt type was designed to hold 3,500 gallons of water and 4½ tons of coal. This is a decidedly lighter and cheaper tender than the rectangular type for the tare weight is exactly the same for this 3,500-gallon tender as for the 2,200-gallon rectangular type used for the compounds. The coal space is much better arranged also, for all coal passes through the self-trimming box on this tender in a few days at most, and no building-up of back and side walls is required while the fireman gets all his coal

Reciprocating Weight.

Acting at 13-in. crank radius and 32½ in. from longitudinal centre line of engine.

Part.	Estimate.	Actual.
	lb.	lb.
Piston head, rod and nuts	222	220
Crosshead, pin, union link and bottom end lap and lead rod	230	237
Connecting rod—little end + ½ big end ..	148	145
Total	600	602

Revolving Weights.

Acting at 13-in. crank radius showing transverse distance "X" from longitudinal centre line of engine

Part.	Leading.		Driving.		Trailing.		X in
	Estimate.	Actual	Estimate.	Actual	Estimate.	Actual	
Connecting rod ½ big end ..	—	—	162	163	—	—	32½
Side rod ..	100	93	182	185	91	91	27½
Crank-pin ..	18	—	81	—	18	Drivers	28
Crank boss ..	103	—	103	—	103	—	31½
							22½
Total ..	221	—	528	—	212	—	—
Balance weight at 13-in. crank radius	307 at 165 deg. behind left-hand crank		688 opposite crank		307 at 165 deg. behind left-hand crank		22½
Reciprocating weight, balanced	155½		160		164½		

Total reciprocating weight unbalanced = 122 lb. =

$$\frac{\text{Reciprocating weight}}{5} - \frac{\text{Total weight of engine}}{900}$$

Distance of wheel contact with rail from longitudinal centre line of engine = 22 in. Right-hand crank leads.

Comparison of Disturbing Forces.

At speed in miles per hour = diameter of drivers in inches.

Method of Balancing.	Proportion of reciprocating Weight Balanced.	Oscillating Force in Lb.	Nosing Moment in In.-Lb.	Hammer Blow in Lb.
English ..	½	11,700	602,264	6,760
	¼	7,020	450,164	8,153
American ..	½	11,700	1,099,878	4,916
	¼	7,020	994,570	6,060
Minimum hammer blow ..	½	11,700	1,362,764	4,030
Minimum hammer blow .. (Method used.)	¼	7,020	1,362,764	4,810

ready to his scoop and never needs to shovel forward as with the other type.

The first engine built of the type above described was tested on the express run from Christchurch to Timaru against the best compound available. Each engine hauled the train out and home for five consecutive days, doing 200 miles per day, and the result of the 1,000 mile test was decidedly in favour of the new engines. The detailed record, Table I, annexed, shows the saving as 20 per cent. in water and 33 per cent. in coal, and this includes coal used in making up the fire each morning and during the 2 hours' stand over at Timaru.

This train is now being run by the new engines exclusively, and the saving in coal and water is being realised steadily. Part of the saving is undoubtedly due to the boiler, which is easily the best steaming boiler seen on a locomotive in New Zealand, but of this saving part again is directly due to superheating. However, without indicator diagrams and tests made on a testing plant under exact conditions it is extremely difficult to apportion the figures with any degree of accuracy. The broad facts remain that this superheated simple engine saves about 30 per cent. coal over the saturated compounds, which again are quite 25 per cent. better than the saturated Baldwin simples they superseded on this run in 1907. These latter engines were the first 4-6-2 engines ever built, and it is on account of these engines that the name "Pacific" was given to the type, so New Zealand has every reason to be proud of its association, with the class, which is undoubtedly the most suitable for the conditions involved.

The saving in coal effected by these new engines was not the only advantage. The compounds, while capable of handling 15 cars on the express run under favourable conditions, could be regularly trusted with only 14. The capabilities of the new engine in this respect could not be fully ascertained as traffic restrictions fix the maximum load at 20 cars, which load the new engines handle with ease, and make up a good deal of time when necessary. Probably the finest performance ever recorded on the 3-ft. 6-in. gauge was accomplished on January 29, 1916, when a train of 20 heavily loaded cars was brought from Timaru to Christchurch under difficult conditions. Traffic delays inseparable from holiday traffic were accentuated by a hot box on a car, so that 22 minutes had to be made up. This reduced the actual running time for the 100 miles to 147 minutes, but despite a heavy north-west gale, a train weighing 423 tons behind the tender, carried on 80 axles, and over 950 ft. in length, was brought to Christchurch on time, although a signal stop at the platform made actual arrival 4 minutes late.

Allowing 2 minutes for each start and stop the average running speed works out on this occasion at 46 m.p.h., a notable performance for an engine with 54 in. drivers and only 30 tons adhesive weight, with a train of 420 tons. The log for this run is as follows :—

Mileage.	Station.	29.1.16		Timetable.	Remarks.
—	Timaru ..	dep.	4 16	4 11	Holiday traffic—5 minutes late.
11½	Temuka ..	arr.	4 34	4 31	3 minutes delay.
	,, ..	dep.	4 39	4 33	
18½	Orari ..	arr.	4 55	—	3 minutes delay.
	,, ..	dep.	4 58	4 51	
47	Ashburton	arr.	5 41	5 38	6 minutes delay.
	,,	dep.	5 52	5 43	
64	Rakaia ..	arr.	6 15	6 11	5 minutes delay.
	,, ..	dep.	6 22	6 13	
100	Christchurch	arr.	7 13	7 10	Delayed 4 mins. outside platform.

TABLE I.—Summary of Locomotive Tests.

Express Service, Christchurch—Timaru. 15/2338.

Trip	AB 608—Simple Superheated—Weight, 75 tons. (December 13 to 17, 1915.) Gross Ton Mileage.	Actual Running Time.	Per Round Trip. Water.	Coal.	Per Ton-Mile. Water.	Coal.	Weather.
		mins.	lb.	lb.	lb.	lb.	
S	25,100	179	50,000	5,544	0·833	0·092	Calm.
N	34,900	165					Calm.
S	26,800	176	48,000	5,576	0·842	0·098	Light N.E.
N	30,200	167					Light N.E.
S	27,500	177	49,500	5,488	0·796	0·088	Calm.
N	34,700	162					Light N.E.
S	33,400	157	51,000	5,600	0·790	0·087	StrongN.W.
N	31,200	179					StrongN.W.
S	35,200	171	49,000	5,432	0·717	0·079	Calm.
N	33,100	165					Calm.
Avg.	31,210	170	49,500	5,488	0·793	0·088	—

Trip	A 399—Compound Saturated—Weight, 69 Tons. (January 10 to 14, 1916.) Gross Ton Mileage.	Actual Running Time.	Per Round Trip. Water.	Coal.	Per Ton-Mile. Water.	Coal.	Weather.
		mins.	lb.	lb.	lb.	lb.	
S	36,500	178	68,000	8,176	0·991	0·119	Calm.
N	32,100	165					Calm.
S	39,600	174	69,000	8,400	0·936	0·114	Calm.
N	34,100	166					Calm.
S	*32,700	175	72,000	9,396	1·03	0·135	StrongN.W.
N	*37,100	168					Light N.E.
S	*33,100	155	70,000	9,408	1·07	0·144	StrongN.W.
N	*32,100	173					StrongN.W.
S	29,100	184	62,500	7,840	1·05	0·132	Calm.
N	30,400	164					Calm.
Avg.	32,960	172	66,500	8,133	1·007	0·123	—

——	AB 608.	A 399.
Coal per engine mile .. .. lb.	27·44	43·66
Coal per ton-mile .. .. .. lb.	0·0880	0·1232
Water per engine mile .. .. lb.	247·5	332·5
Water per ton-mile .. .. lb.	0·793	1·007
Ton-miles per lb. of coal	11·38	8·114
Ton-miles per lb. of water	12·60	9·925
Lb. of water evaporated from and at 212 deg. F. per lb. of coal	11·96	9·87

AB 608 saves 33 per cent. coal and 20 per cent. water over A 399

S = Christchurch–Timaru. N = Timaru–Christchurch. (100 miles.)

* Not counted in average; strong wind.

Coal accurately weighed and water measured by meter.

TABLE II.—Summary of Locomotive Tests.

Express Service, Wellington—Taihape. 16/1414.

Trip	AB 658—Simple Superheated—Weight, 75 Tons. (September 4 to 12, 1916.) Gross Ton Mileage.	Actual Running Time.	Water per Journey.	Coal per Round Trip.	Per Ton-Mile. Water.	Coal.	Weather.
		min.	gall.	lb.	gall.	lb.	
N	53,200	327	5,085	10,416	0·096	0·096	N.W. gale.
S	55,200	318	3,710		0·067		Fair.
N	49,600	328	4,910	11,228	0·099	0·110	N.W. gale.
S	52,550	332	3,440		0·065		Calm.
N	49,200	337	4,070	11,788	0·083	0·111	Calm.
S	56,650	325	3,600		0·063		S. gale.
N	53,850	336	4,935	11,312	0·091	0·103	N.W. gale.
S	55,800	333	3,455		0·062		S. gale.
Avg.	53,260	330	4,150	5,593	0·078	0·105	—

Trip	A 598—Compound Saturated—Weight, 69 Tons. (September 15 to 21, 1916.) Gross Ton Mileage.	Actual Running Time.	Water per Journey.	Coal per Round Trip.	Per Ton-Mile. Water.	Coal.	Weather
		min.	gall.	lb.	gall.	lb.	
N	44,260	340	4,720	11,844	0·107	0·127	Calm.
S	48,860	339	4,280		0·088		Calm.
N	50,260	341	5,230	12,684	0·104	0·119	Calm.
S	55,900	327	4,710		0·084		Calm.
N	41,025	345	4,430	10,836	0·108	0·117	Calm.
S	51,855	300	4,515		0·087		Calm.
Avg.	48,700	332	4,648	5,894	0·095	0·121	—

——	AB 658.	A 598.
Coal per engine-mile .. .. lb.	35·00	36·8
Coal per ton-mile .. .. lb.	0·105	0·121
Water per engine-mile .. .. gall.	26·00	28·00
Water per ton-mile .. .. lb.	0·78	0·95
Ton-miles per pound of coal	9·7	8·26
Ton-miles per pound of water	1·28	1·05
Pounds of water evaporated from and at 212 deg. F. per pound of coal ..	9·84	9·52

AB 658 saves 13·2 per cent. coal and 17·9 per cent. water over A 598.

Each engine was assisted Wellington–Johnsonville on north trip; in addition, A 598 was assisted Marton–Taihape on September 15, 1916, Paekakariki–Wellington on September 19, 1916 and September 21, 1916, and Palmerston–Taihape on September 20, 1916.

Coal accurately weighed and water measured by meter.

The success of the new engines on this run, particularly the abolition of double heading, caused the building of 20 of these engines to be pushed on, and some were brought to the North Island and now work the main trunk expresses between Wellington and Taihape, and between Auckland and Taumarunui. A series of tests was carried out in the North Island between the new engine and the compound. The results are given in Table II. The water saving was about the same in this case, but the coal saving fell off, partly due to the long drifts down hill and the undulating nature of the road generally, which prevents regular conditions obtaining. However, the superiority of the "Ab" in coal and water consumption was clearly established, while its load hauling capacity has caused all double heading to be cut out, though a banking engine is still frequently used on the first 5 miles out of Wellington, where there is a grade of 1 in 40 with uncompensated curves of 7 chains radius.

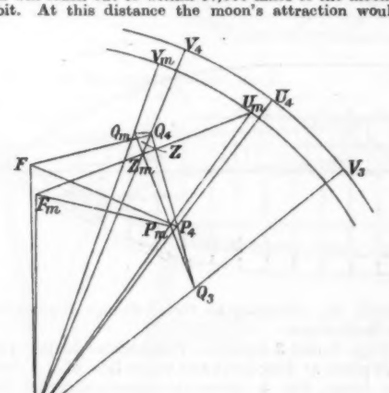
A notable feature is the fact that the large tender and small water consumption cuts out two of the three stops formerly made for water and the 87 miles from Wellington to Palmerston North is now a non-stop run both ways, the only notable one in New Zealand. The engines described are great favourites with the crews, and have given such satisfaction in general use that they are now looked on as standard engines for both passenger and goods services for main line runs, and will be the only tender engines built till such time as heavier axle loads are allowed.

THE ELLIPTIC TRAJECTORY OVER THE EARTH.

To the Editor of Engineering.

Sir,—Sir George Greenhill's papers on the elliptic trajectory in Engineering of October 11 and 18, bring us nearly to the problem discussed by Jules Verne of a projectile fired from the earth and passing round the moon. It is interesting to consider whether a shot could be fired from the earth in such a manner as to be disturbed by the moon's attraction so that on its return journey it would miss the earth and pass round in an elliptic orbit, thus becoming a tiny satellite.

A shot fired from the earth with a velocity of 5¼ geographical miles per second, at an angle of elevation of 29 deg., will describe an ellipse of semi-major axis 65,000 miles, eccentricity 0·96. The orbit will pass, if undisturbed, 830 miles inside the earth's surface, and will reach out to within 87,000 miles of the moon's orbit. At this distance the moon's attraction would



(5659)

draw it 23 miles in 3 hours. The time of revolution of the orbit would be five days. It is to be supposed that the moon lies in the plane of the orbit and to one side of the major axis.

The perturbations by the moon can be shown by a geometrical construction in the Newtonian method of discrete impulses provided it can be drawn in a scale large enough to show the small variations, or in any case the variations of the angles and distances can be measured trigonometrically. Following Sir George Greenhill's line of reasoning by the accompanying figure corresponding with his Fig. 4, page 395 *ante*, it is supposed that during the path from Q_3 to Q_4 the moon's attraction draws the body through a path represented by Q_4 Q_m, so that the resultant path is represented by Q_3 Q_m. Then Q_3 Q_m is the tangent to the new ellipse in which (supposing the path Q_3 Q_m to be indefinitely small) the body would continue to move if the disturbance ceased to act. Bisect the angle Q_3 E Q_m by the line E P_m meeting Q_3 Q_m at P_m. This is the point where the tangent touches the ellipse. Through P_m draw P_m F_m making the angle Q_m P_m F_m equal to the angle between Q_m P_m and E P_m produced. The new focus F_m lies along this line at a distance F_m Z_m from Q_3 Q_m proportional to the velocity. Clearly

$$\frac{F_m Z_m}{FZ} = \frac{Q_3 Q_m}{Q_3 Q_4}$$

which determines F_m. Produce F_m Z_m to U_m, making F_m U_m = 2 F_m Z_m; then the circle with radius E U_m is the new hodograph circle. Since E P_m + P_m F_m = the major axis, the new ellipse is completely determined. The subsequent movement of the body can be followed by repeating this construction, taking for the next period an angular interval equal to V_3 E V_m.

Yours faithfully,

Guy B. Petter.

7, Princes-street, Yeovil, November 6, 1918.

"COAL SAVING BY SCIENTIFIC CONTROL OF STEAM BOILER PLANTS."

To the Editor of Engineering.

Sir,—I have read with the greatest interest both Mr. Brownlie's articles and the correspondence that has resulted, but I think that before discussing the knowledge and capabilities of the fireman, perhaps it would be better to educate the engineer in charge of the plant in the principles of chemistry and physics which govern the economical performance of boiler plant.

I do not think I am mis-stating the position when I say that the average steam service engineer in an industrial establishment (as distinct from electric power stations) is not, by the general nature of his training, sufficiently qualified to obtain the best results from his steam-raising plant, his only concern usually being to maintain the steam pressure at its proper level. In fact, I have heard the steam-service engineer in charge of a very important plant in this district express the heartiest contempt for the atmosphere of "economy craving" to be found in electric power houses.

The economies obtained by perfected lagging, stoppage of steam leakage both from pipe joints and past engine pistons do not reach the root of the matter, which lies with the generation of steam in the boiler, and it is here that the greatest saving can be effected. It is very common indeed to see boilers unprovided with any means of operating the dampers from the firing floor, and this in itself is sufficient to indicate that the plant is not giving its best efficiency. The secondary air supply arrangements are also often very ineffective. These are only two points among many, and I have no hesitation in asserting that any installation of boilers, say of 10 upwards, should be in charge of a properly qualified engineer who has specialised in this class of work and is therefore acutely conscious of the importance of many points which to the general engineer may appear quite insignificant.

Meanwhile, if all engineers in charge were to make themselves thoroughly conversant with the use of pyrometers, draught gauges and the Orsat apparatus and the deduction to be drawn from the indications of these instruments, we should without doubt see a considerable improvement in the efficiency of boiler plants as a whole.

Yours truly,

Chas. F. Wade, A.M.I.E.E.,
(Boiler and Fuel Economy Expert).

Sheffield.

To the Editor of Engineering.

Sir,—I have read with interest Mr. Anderson's letter in your issue of to-day and take this, the first, opportunity of hoisting the white flag and saying I am sorry I misunderstood his remarks relative to stokers, as evidently we agree they are on the whole jolly good fellows. With reference to Mr. Anderson's comment on Lancashire boilers, however, I maintain if such are seated and worked on the lines indicated in my letter to Engineering, August 30, the Lancashire boiler can be worked as efficiently as the majority of water-tube boilers.

Mr. Anderson's reference to the Yorkshire boiler compels me to speak on a subject I have refrained from mentioning in my previous letters, not for any other reason, however, than that of a natural objection to introduce into a public discussion the personal element. I would now, however, state, that it is due to the high duty and efficiency secured with the Yorkshire boiler that I have been able to establish a law which, when applied to Lancashire boilers, increases as a rule their efficiency fully 10 per cent. without in any way impairing the hourly duty (see Tables "A" and "B" given in my letter, September 28). In the Yorkshire boiler the ratio of grate area to outlet from the furnace flues is 1·8 to 1, and this applies to all sizes of boilers, whereas in the Lancashire fitted with standard grates the ratio ranges from 4 to 1 in a 7-ft. diameter boiler to 2½ to 1 in a boiler 9 ft. in diameter, thus making uniform duty per square foot of grate in different diameter boilers impossible.

Once the fact is fully recognised that a ratio of 2 to 1 between grate and outlet from the furnace flues in a Lancashire boiler gives the higher efficiency and makes black smoke impossible the coal consumption in this country will drop many millions of tons per year.

Mr. Brownlie's report, July 12 and 19, gives a range of over 30 per cent. between the efficiencies of his minimum and maximum tests, and my own results during the last few months verify his figures.

Seeing that we have a few Lancashire boilers well seated and designed and working on scientific lines, giving over 80 per cent. efficiency, we cannot say there is any fault in the boiler itself, as in over 80 per cent. of our steam plants the fault will be found entirely due to the grates being too big for the outlets for the gases at the end of the boiler furnace flues.

Yours faithfully,

W. H. Casmey.

Milnthorpe, Wakefield, November 18, 1918.

WOMEN IN THE DRAWING OFFICE.

To the Editor of Engineering.

Sir,—It is pleasant to find that Mr. Morgan has taken my attempt to prevent a misunderstanding in such good part. He is, moreover, quite right, since, apparently, he has been misreported. The statement to which we took exception appears in Engineering as, "Women are specially suitable for such semi-skilled operations as tracing and draughting," whereas in a copy of his paper which Mr. Morgan has sent me it appears, "Women are specially suitable for such skilled, and semi-skilled operations, &c.," which, of course, is a very different thing. Later on Mr. Morgan emphasises the necessity for preliminary training, and I note that he speaks only of "junior" draughtsmen.

Whether, in the interests of the engineering industry it is desirable to employ women as junior draughtsmen when it is not anticipated they will develop into seniors, is open to serious question, because if they are crowded out of the junior ranks, one wonders where the senior draughtsmen are to get their early experience. If I may say so, this is a tendency noticeable throughout the paper—a tendency to look at the problem merely as one of the employment of women, and not so much as of the future efficiency of the industry as a whole.

Yours faithfully,

Ernest H. Walker
(Chairman National Executive).

61, Claverton-street, S.W.1,
November 18, 1918.

To the Editor of Engineering.

Sir,—I have studied Mr. Ernest Walker's letter in your issue of November 8 with a great deal of interest, more especially his stirring call "ladies . . . look up your mathematics, your mechanics, your geometry." I can only suppose that he is not aware that several women have taken engineering degrees at the universities, and that they are now engaged, in connection with engineering and aeroplane work, in mathematical calculations of which many draughtsmen would be justly proud. With regard to their work in the drawing office, it is true that women have, until a few years ago, been debarred from obtaining the necessary shop experience, but this handicap does not apply to the same extent to some of the calculating work which in many firms is carried on in connection with the drawing office.

I have several examples of such work done by women, which I shall be very pleased to show to Mr. Walker.

May I say, in conclusion, that I cordially welcome his statement that women will be employed willingly as draughtswomen when they can do the work of draughtsmen; can I conclude from this that they are eligible for membership of the Association of Engineering and Shipbuilding Draughtsmen on the same terms as men?

Yours faithfully,

Rachel M. Parsons.

1, Upper Brook-street, W.1, November 19, 1918.

Export Prices of Steel.—The Minister of Munitions has given notice that all deliveries of steel for export shall continue to be made at prices fixed by the Minister. Information as to the export prices ruling on and after November 18 will be obtainable on application to the Ministry of Munitions (Controller of Iron and Steel Production), Whitehall Place, S.W.1.

Relaxation of Petrol Restrictions.—The Board of Trade, after consultation with the Petroleum Executive, announce that it will not be possible for some time to withdraw entirely the restrictions on the use of petrol for driving motor vehicles. H.M. Petroleum Executive are making arrangements to provide as quickly as possible increased supplies of petrol to be distributed by the Petrol Control Department for civilian purposes. The assumption that the cessation of hostilities would result in an immediate increase in the quantity of petrol available for civilian consumption is ill-founded. As a matter of fact, the conditions resulting from the armistice have already involved a material increase in the consumption of petrol in connection with the Army in France, and the increased heavy demand in this respect will continue for some little time. On the other hand, it will take some time so to adapt the shipping position as to enable increased supplies to be brought into the country. Arrangements are being made at once for the transfer of ships which have been carrying fuel oil to the purpose of carrying petrol, but on account of the necessity for cleaning the ships it will be several weeks before they will be ready. In the meantime, having in view the greater facilities which will be available for increasing the petrol stocks later on, the Board of Trade will be able to some extent to relax the restrictions at an early date. It is therefore proposed that: (1) The Motor Spirit (Consolidation) and Gas Restriction Order, 1918, shall be modified so as to permit, on and after December 1 next, the use of motor spirit by licence-holders for driving motor vehicles of any type for all purposes within a radius of 30 miles of the place of residence or business of the licence-holder. So far as journeys beyond this radius are concerned the restrictions will for the present remain in force. They will, however, be removed entirely as soon as it is possible to do so. (2) After January 1 next, if the condition of the stocks of motor spirit at that time permits, the Petrol Control Department will be prepared to consider application from owners of commercial and public utility vehicles for an increase in their present allotments. Applications for licences will also be considered from owners of vehicles of this type who do not at present hold licences. It is also anticipated that, within a short period afterwards, the department will be in a position to consider applications for licences from private vehicle owners who do not at present hold licences, and for increased allotments in the cases of existing licence-holders. It must be understood, however, that for some time to come motor spirit will only be obtainable under licence by the Petrol Control Department as hitherto.

THE WALLER SYSTEM OF REINFORCED-CONCRETE SHIP CONSTRUCTION.

By W. Noble Twelvetrees, M.I.Mech.E., M. Soc. Ing. Civ.

A portion of Lake Shipyard, Poole, has been allocated to barge building on the Waller system, Messrs. Hill, Richards and Co., Limited, being the contractors responsible to the Controller-General of Merchant Shipbuilding, while the supervision of the work devolves upon Captain J. H. de W. Waller, D.S.O., R.E., in pursuance of an arrangement made by the Admiralty and the War Office. Captain Waller is a partner of Messrs. Delap and Waller, civil engineers, Dublin, and has made a special study of reinforced concrete construction both in the United States and in the British Isles. He acted as one of the engineers on behalf of the Waterford Bridge Committee during the construction of the ferro-concrete bridge over the River Suir, between Waterford and Ferrybank, and since then has executed in reinforced concrete several important public works of his own design.

Since the outbreak of hostilities he has been on active service, mainly on the Eastern front, and has made various applications of concrete, both plain and reinforced, in structural works for military purposes. Having been struck with the possibilities of reinforced concrete in shipbuilding, he has devised a method of construction, the chief objects of which are to produce reinforced concrete of the highest possible quality and at the same time to reduce the cost of materials and labour by the employment of pre-cast plates in combination with frame members moulded *in situ*. Having brought this system to the notice of the Admiralty, Captain Waller received instructions to complete a design for an experimental vessel and to superintend its construction at the Poole shipyard.

Owing in part to the fact that materials are drawn from the stores in the main shipyard, and in part to the simplicity of the Waller system, the plant and equipment in the branch yard have involved comparatively little outlay, as may be judged on reference to the block plan in Fig. 1.

The slipway on the water's edge was constructed on the same principle as those in the other part of the shipyard, and is connected with the works department by means of a light railway. The buildings include offices for Captain Waller, draughtsmen and clerks, a carpenters' shop where timber is prepared for use as framing and shuttering on the slipway, a bar-bending department with concrete platforms for verifying the profile of bars which have been bent to required shapes, and a shed accommodating a concrete mixer.

The pre-cast concrete plates are moulded in the open air on a series of concrete beds. The network of bars for each plate is assembled in a timber frame, the sides and ends of which serve as moulds for the edges of the plate. The upper face of each plate is

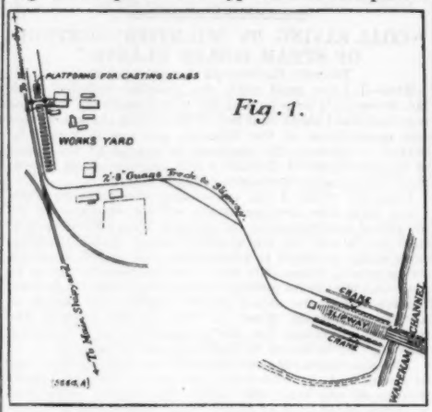


Fig. 1.

trowelled while still green, and after it has been covered with a coat of whitewash, the next plate is moulded upon it, the processes being repeated until the stack of plates has reached the limiting height for convenient handling. The contractors' line running down to the slipway is alongside the plate-moulding beds, and the plates are conveyed to their destination on trucks of special design.

The simple character of the plant in the works department is equalled by the simplicity of work on the slipway. Inasmuch as the plates forming the sides, bottom and deck of the ship have been prepared and seasoned in advance, they have merely to be erected and stayed in place, and the only moulds required are those for the longitudinal and transverse members of the framework. In order to provide secure anchorage between the several elements, the plates are cast with the reinforcing bars projecting along all four sides, and arrangements are made for the intermeshing and interlocking of these bars with those of adjacent plates and of members moulded *in situ*. Apart from the use of pre-cast plates in the manner which has been briefly outlined, a special feature of the vessel now under construction is the concentration of the main longitudinal reinforcement for withstanding hogging and sagging stresses, in the bilges and gunwales. The vessel is, in fact, designed somewhat on the lines of a through girder bridge, the principal longitudinal stresses being taken by the parallel girders constituting the sides of the vessel.

Similarly, the principal transverse stresses in the deck and bottom are resisted by the transverse frames. These points will be appreciated more clearly by reference to the drawings reproduced as illustrations.

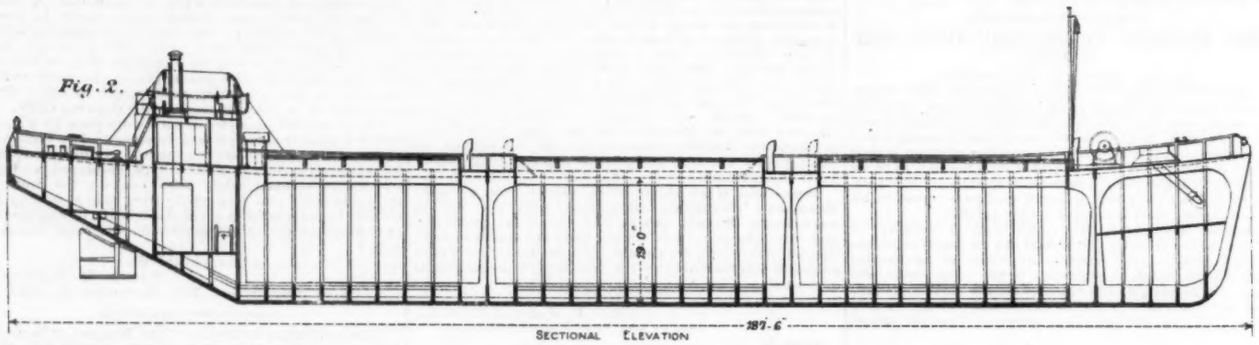


Fig. 2.

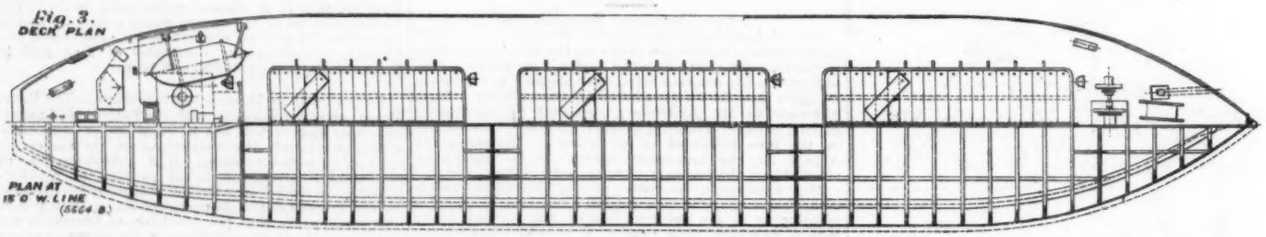


Fig. 3.

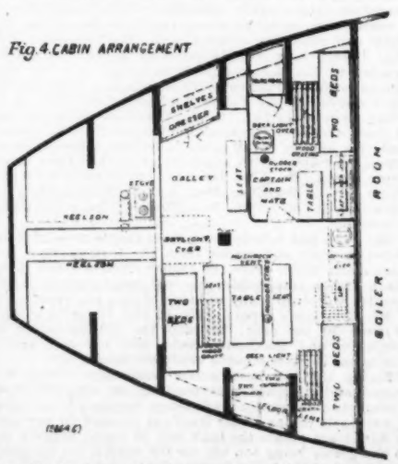


Fig. 4. CABIN ARRANGEMENT

Figs. 2 and 3 include a longitudinal section and half plans at deck level and water line of a 1,000-ton barge, Fig. 4, shows the accommodation for captain and crew. The vessel to which these drawings refer was designed so that flat plates could be used throughout, as an alternative to the adoption of specially curved plates for the bow and stern, or moulding these parts in shuttering.

The design is further illustrated by the cross-sections reproduced as Figs. 5 to 7. Being in general accordance with the plans and specifications of the Department of Merchant Shipbuilding, the barge measures 187 ft. 6 in. in length overall, 32 ft. 10 in. in breadth at deck level, and 19 ft. in depth from deck to keel. It has three holds, two 46 ft. in length, and one 37 ft. in length, the mean width in each case being 29 ft. approximately. The fore peak with an intermediate deck provides accommodation for stores and a chain locker; on the upper deck a steam winch will be installed, and the usual provision is made for the anchor and other details. Immediately abaft the third hold is the boiler room, with the deck house, bridge, and boat platform above. Under the main deck behind the deck-house are the quarters for the captain, mate and crew, details of which are given in Fig. 4.

The transverse bulkheads at the ends of the holds are built up of pre-cast plates incorporated with counterforts, extended at the foot and head to a

width of 4 ft. 6 in. from the vertical axis. The counterforts are spaced 4 ft. apart, transversely, and are in monolithic connection in each case with three of the transverse frames at the top and bottom of the hold. Consequently they form part of the main framework, and afford secure support for the decking between, or at the ends of, the hatchway coamings.

The longitudinal section and the sectional plan at water line in Fig. 2 make clear the arrangement of the transverse members of the main framework, decks, bottom and sideplates, bulkheads and interior partition walls, but do not show the longitudinal members so clearly, and necessarily omit the top and bottom booms of the girderlike construction of the side walls.

As before mentioned, the concentration of reinforcing bars along the bilges and gunwales, with a suitable covering mass of concrete, is relied upon for resistance to the principal longitudinal stresses. The upper and lower booms are connected by a web formed by the side plates, and the transverse frames act as stiffeners, the frames being connected about half-way up by a continuous stringer.

Figs. 5, 6 and 7 show the profile of the frames at different parts of the ship and the arrangement of the main and secondary reinforcement. An interesting departure from usual practice is the curved form of the frames. This form is not only conducive to strength but is considered by the designer to distribute more effectively the deformation of the frames and so reduce the tendency of the skin to rupture. The upper cantilever portion provides support for the deck over the holds without the employment of either brackets or obstructive columns in the interior. The bars in the bilges and gunwales are of 2 in. diameter, those in the frames are of 1¼ in. diameter, and the secondary reinforcement consists of ties or stirrups made of ¾ in. rods disposed at varying intervals. The frames are 2 ft. 10 in. deep over the bottom of the vessel, the depth of the side arms ranging from 1 ft. 6 in. upwards, while the thickness is 5 in. throughout.

Wherever shearing stresses permit such a course to be followed, the web of the frames is panelled to reduce the dead weight of material. The stringers in the midship part of the vessel are 15 in. by 3 in. in cross-section, and they are reinforced by 1¼ in. diameter bars and transverse links, as shown in Fig. 5.

This drawing also shows the centre keelson in cross-section and represents some of the bulkhead counterforts in elevation with the top and bottom extensions in section. It will be noticed that the main bars are hooked at the ends for secure anchorage and disposed so as to provide for effective connection between different elements of the construction.

Having briefly outlined the general character of the construction, we now come to some important details upon the efficiency of which depends the reliability of the Waller system of shipbuilding. The chief objection entertained by those who favour monolithic construction against the employment of pre-cast units joined together by frame members moulded *in situ*, is that the joints will most probably be broken by the hogging, sagging and twisting stresses that will be developed when the vessel is in service on the sea.

The reply of designers who have adopted the pre-cast system is to the effect that joints actually exist in all vessels which are theoretically monolithic; that the positions of such joints are not predetermined but are governed by circumstances demanding the interruption of concreting work from time to time; that the positions of the joints

Fig. 5.

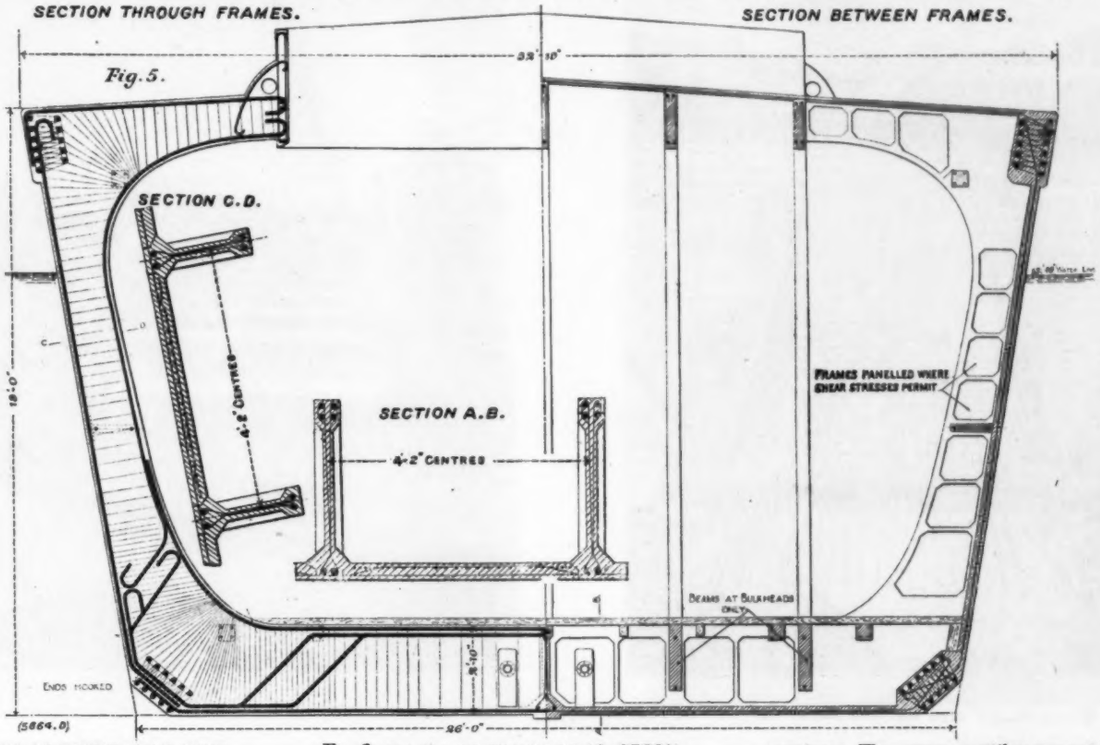


Fig. 6.

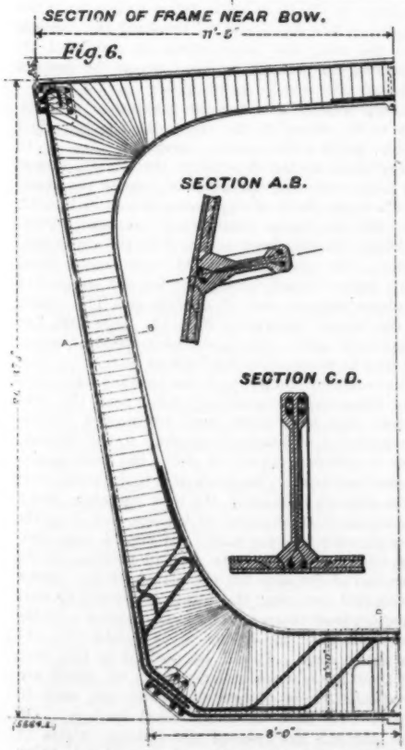
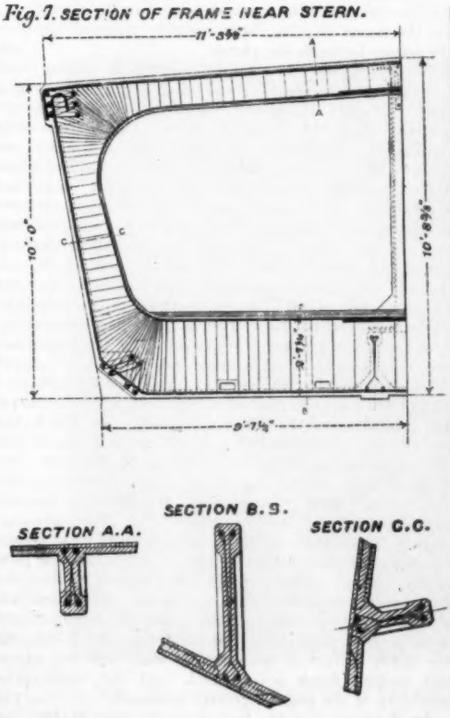


Fig. 7. SECTION OF FRAME NEAR STERN.



THE WALLER SYSTEM OF REINFORCED-CONCRETE SHIP CONSTRUCTION.

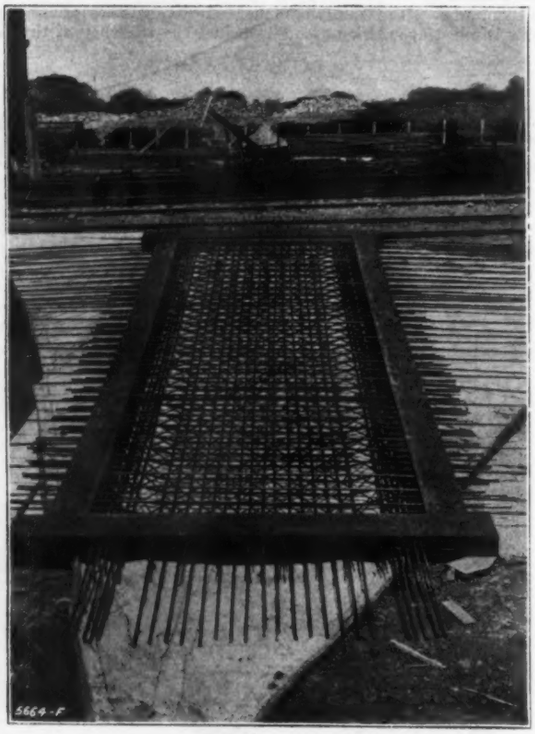


FIG. 8. MOULD FRAME WITH REINFORCEMENT FOR BOTTOM PLATES.

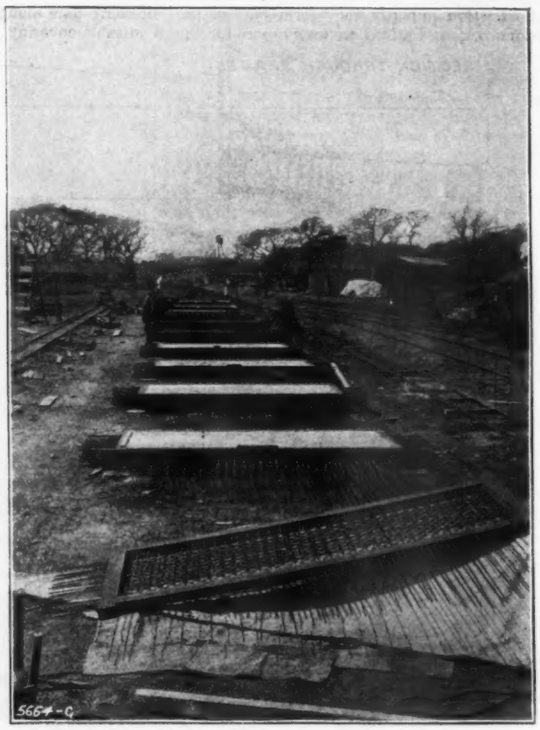


FIG. 9. CONCRETE PLATE MOULDING YARD.

in the pre-cast system are always predetermined, thus permitting the surface to be arranged in the most suitable direction and giving opportunities for the disposition of interlocking reinforcement; and that the joints so made are not less efficient than those occurring in what is called monolithic construction. In the case of the Waller system, the further reply is made that the principal stresses are resisted entirely by the main framework which is moulded on the monolithic principle, and that the plates, although helping by offering resistance to shearing stresses, are mainly intended to act as the skin of the vessel, being analagous to the plates of a steel ship.

The bottom of the barge is formed of two rows of plates, 3 in. thick, each plate being 11 ft. long by 3 ft. 6 in. wide, approximately, the end joints occurring at the bilges and centre keelson, and the side joints at successive transverse frames. The sides are formed of plates about 15 ft. 6 in. long by 3 ft. 6 in. wide by 3 in. thick, the end joints being at the gunwales and bilges, and the side joints at successive transverse frames. The deck plates are only 2 in. thick and are jointed at the gunwales and hatch coamings. The foregoing dimensions are those referring to the midship portion of the vessel, the length of the plates for the fore and aft peaks being in accordance with varying requirements, as shown by the typical sections given in Figs. 5 to 7.

All the joints are in planes at right angles to the longitudinal axis of the vessel, and the edges of the plates are chamfered as indicated by the various small sections in Figs. 4 to 6, while the rods projecting from the pre-cast plates along all four sides are bent up perpendicular to the plates and passed around the bars placed in position for the members which are to be moulded between the plates.

The rods as so bent serve the purposes of holding the bars in correct alignment and of acting as web reinforcement in the members to be moulded, while at the same time establishing continuity between the two classes of work. Before the joints are made, the edges of the pre-cast plates are roughened, and the concrete afterwards deposited in the moulds are the frame members is thoroughly rammed into the spaces between the plates.

In this and other systems embodying the employment of pre-cast units, everything depends upon the care with which the joints are made, and practical data will in due course be available concerning the reliability of such methods under service conditions. In the meantime, it is interesting to know that a severe test conducted at Lake shipyard on joints made in accordance with the Waller system resulted in fracture of the concrete along a line close to and roughly parallel to the joints, but not along the joints themselves, a result showing the adhesion of new and old concrete in a distinctly favourable light. Practical construction at Poole on the Waller system is illustrated by the series of photographs reproduced on the present and opposite pages and on page 586.

Fig. 8 shows the edge mould for one of the pre-cast plates with the reinforcing network in position and projecting at the sides and ends. Fig. 9 is a general view of 10 moulding beds and plates in course of being made, the contractors' line running alongside.

Apart from the saving of time and shuttering, the objects aimed at in moulding the plates in the manner described are to ensure the absolutely correct disposition of the reinforcement with a minimum amount of trouble and to obtain concrete of the highest possible quality and surface finish. By moulding on the flat, the concrete can be rammed to any extent desired, and the operations are open to inspection throughout. Moreover by trowelling the upper surface of the concrete while still wet a fine surface finish is obtained, and the impermeability of the plate is greatly increased.

An illustration of the last point, Captain Waller states that samples of a plate, 2 in. thick, finished under working conditions were tested and were found capable of withstanding a head of water of 480 ft. for 2 hours without leakage, and after the expiration of that period, did not allow actual leakage, what took place being best described by the term "sweating."

A head of 120 ft. of water failed to penetrate the samples in five days, and on breaking the samples after the test, the penetration, as indicated by dampness, was not more than $\frac{1}{4}$ in. at the deepest place.

As the plates used for the bottom of a barge have to be placed in the ship with the trowelled surface below, the most convenient plan is to convey them to the slipway in the same position, and to facilitate the operation of turning the plates over, a simple form of apparatus, shown in Fig. 12, page 586, has been constructed near the moulding beds. Having been reversed by the aid of this machine, the plates are loaded upon trucks fitted with a frame of sufficient length for the support of the plates without risk of overstrain. The plates on the trucks shown in Fig. 13, page 586, are actually side plates, but a similar method of transportation is adopted for the bottom plates.

The concrete mixer and bar-bending shop are quite close to the moulding beds, and the contractors' line has proved very convenient for the conveyance of all kinds of materials to the slipway. When a sufficient supply of plates has been manufactured in advance, the work of actual construction at the slipway is started, the first operation being to place the bottom plates on timbers laid along the series of concrete cross walls. In Fig. 14, page 586, some of the plates may be seen in position at the shore end of the slip, but the plates are less prominent in this view than the forest of turned-up bars projecting from their edges for incorporation with the reinforcement of the frames to be moulded *in situ* at a later stage. It will be noticed in this view that there are a series of cross walls on which are placed bilge blocks of concrete which are used to support two lines of longitudinal timbers. On these timbers are placed the bottom plates of the barge, no shuttering of any kind being required. While the work of laying the bottom plates is going on, profiles defining the outlines of the vessel are being erected, the temporary framework providing for the support of the side plates which are brought from the moulding

THE WALLER SYSTEM OF REINFORCED-CONCRETE SHIP CONSTRUCTION.

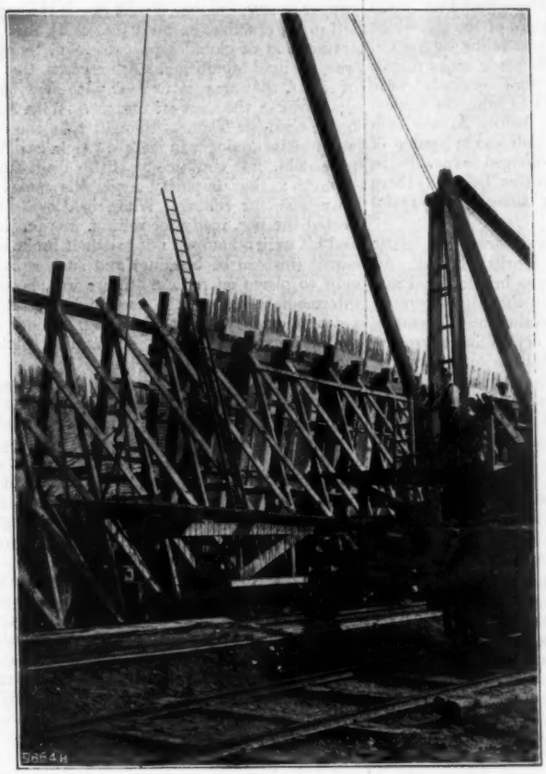


Fig. 10. Arrival of Plates at Slipway.

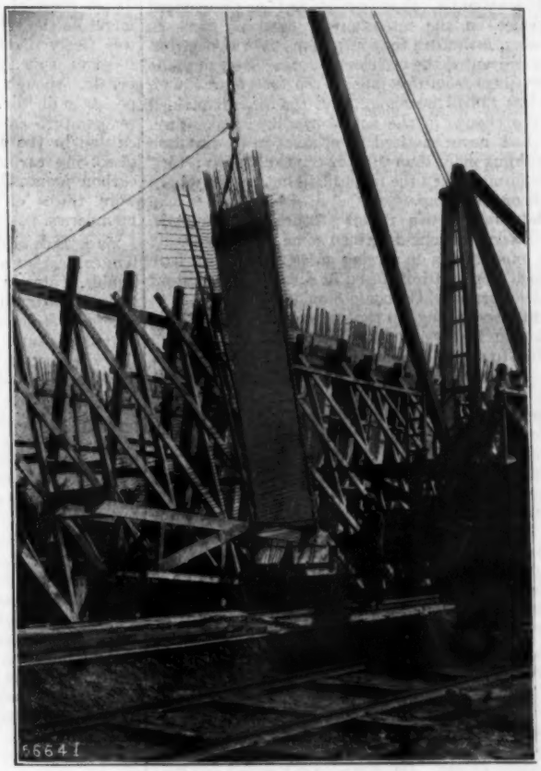


Fig. 11. Hoisting Side Plates.

yard on trucks of the type already illustrated. To facilitate the hoisting of the side plates, two 2-ton travelling derrick cranes are employed, running on tracks laid on either side of the slipway, the two stages in the operation being shown in Figs. 10 and 11. It should be noted that the projecting bars are carefully bent in the required direction before leaving the moulding yard, loops being made by the aid of templates for the insertion of the vertical bars near the outer face of the transverse frames.

Fig. 15, on page 586, is a view taken from the water end of the slipway, representing the interior of the barge with all the bottom plates and nearly all the side plates in position. The next operation is the assembly of the reinforcement for the main longitudinal and transverse members, and after that the concreting of the framework. Fig. 16, annexed, is an interior view showing a number of the transverse frames concreted nearly up to deck level.

On behalf of this system it is claimed that a considerable saving in timber and skilled labour can be effected because the whole of the skin shuttering is eliminated, and that unskilled labour is also economised because the concrete of the plates is deposited at ground level poured quickly into open moulds, instead of being inserted and rammed with some difficulty between double shutters already packed with steel. It is stated that on a 1,000-ton barge, 40 men working at once is an ample number, this being due to the fact that the whole of the skin is prepared independently of the work on the slipway.

In a barge of 1,000 tons deadweight capacity, some 200 plates are required. On each moulding bed, one plate can be cast daily. Therefore, if 40 beds are available, the plates for the entire skin, including bottom, side and deck plates, could be produced in six working days. Experience on the barge now approaching completion indicates that the reinforcement for the transverse frames can be assembled at the rate of four frames a day by a gang of eight men, assuming that the bars are supplied ready bent to the required form. Consequently it is believed that it will ultimately be possible to erect and concrete the hull of a 1,000-ton barge in six weeks, providing the requisite supplies of pre-cast plates and prepared bars are forthcoming from the works department of the yard.

Fig. 16. Concrete Transverse Frames.

The barge now in hand will have taken very much longer, owing to various delays connected with the equipment of the yard and the organisation of work generally.

THE OCCLUSION OF GASES BY METALS.

(Concluded from page 564.)

In concluding our comments upon the discussion of gas occlusion by the Faraday Society, we shall have to deal very briefly with some of the numerous communications presented, and to save space we shall group the contributions as far as possible.

To exemplify the reality of the problem Sir Robert Hadfield had brought up two ingots of absolutely the same kind of mild steel, the one rendered sound by the addition of 0·2 per cent. of aluminium, the other honeycombed. He also mentioned an incident from his own life. His father had made hydraulic cylinders, sound and free from blowholes; they were sent out to India, tested, and yet found to leak under pressure of 3 tons per square inch subsequently; no investigation was possible at the time in India, and the matter was financially very serious. It was afterwards established that the 1 per cent. carbon steel had been annealed, and that 0·4 per cent. of the carbon had turned into graphite.

The question of brittleness was first raised by Professor Porter, who showed that a piece of cobbler's wax, not a solid at all in the ordinary sense, flew to pieces when thrown on the table. Whether or not a substance would appear brittle was a question of time, he stated; if the wax had time to adjust itself to the stress, it would appear viscous; under rapidly-applied stress it was a brittle solid. Dr. W. H. Hatfield brought the discussion back to iron again. Iron containing hydrogen was considered brittle, he said; but all

iron did contain hydrogen, it was a question of amount. With galvanic corrosion the acid ate into the crystalline boundaries and thus rendered the steel brittle. As regards silicon, manganese and aluminium, they really had a pronounced influence on the retention by steel of gases in freezing, favouring that retention; it was not that they prevented the occlusion of gas. He had made 50 castings from one ingot; the first were sound, the last full of blowholes, and that was explained by the change in the actual casting temperature. He had never noticed blowholes in a cast-iron containing more than 0·4 per cent. of silicon; they were formed when the mould had not properly been made or was damp.

Referring to his recent lecture on diamonds, Sir Charles Parsons described some very interesting new experiments on forcing gases under a pressure of tons into cast-iron fused in a crucible within an electric furnace. Carbonic dioxide did not seem to produce any change in the structure. Coal gas and hydrogen had very remarkable effects: the iron swelled to nearly double its volume, and the graphite was segregated into a layer. The hot iron afterwards was white and brittle, near the melting-point it looked mottled. Dr. Hatfield had found very little hydrogen in this iron, but had suggested that the hydrogen permitted a very rapid growth of the graphite through the metal in less than half a minute. When iron was heated in a furnace in air, and then rapidly heated up again in a vacuum, the gas came out so violently that the metal was thrown about. There was evidently some action between the graphite and hydrogen. This view was afterwards confirmed by Dr. H. E. Armstrong, who went further by asserting that graphite was not merely a form of carbon.

Dr. W. Rosenhain's communication on the "Occlusion by Aluminium and its Alloys," diverted the discussion for a time into other channels. He dwelt upon a fact which confronts the inquirer into these problems, viz, that rising temperature may apparently favour both the absorption and the liberation of gas. Dr. Rosenhain pointed out that the absorption might occur when the metal was liquid and hot, and when it was solid and cold; the two phenomena were of different orders. The absorption by molten metals did not follow the ordinary rule of gas absorption by liquid; gas solubility generally decreased as the temperature rose, but according to A. Sieverts* the solubility of gases in certain molten metals increased as the temperature was raised. That was very curious, and seemed to show that the phenomenon was not merely physical, but that chemical compounds such as nitrides, hydrides, &c., were formed, which were more stable at higher than at lower temperatures. But even that was not readily understood, since in most cases very high temperatures tended to bring dissociation of compounds in which a gaseous element was concerned, rather than association. The point was fundamental, and should further be investigated. When a metal in equilibrium with its atmosphere was allowed to cool, did the metal lose gas continuously as its temperature fell, or did it become supersaturated and part with its gas suddenly at or near the freezing point? Watching aluminium and its alloys, he had not noticed any gas evolution until the metal began to solidify. Before that gas bubbles could plainly be seen running underneath the tough skin of the metal; then effervescence set in and lasted until the metal was quite solid. If the gas were to remain in the metal after solidification, it could not be retained in distinct particles, but only in solid solution. A crystal of a solid solution was regarded as being built up more or less indiscriminately, of the atoms of the solvent metal and of the dissolved substance, and could only form when the atomic volumes of solvent and solute were not very different, and when the two could crystallise together. If that were so, crystals built up of metal and hydrogen were difficult to conceive, and the crystals could hardly contain much gas in solid solution; that would account for the fact of the gas being evolved at the moment of crystallisation. On the other hand, solid metals were known to contain gas. Where then was the gas in the molten metal? He suggested, in the intercrystalline cement, which need not necessarily be in the same atomic or molecular condition as the mass of the cooled liquid. Those films of undercooled intercrystalline liquid might be the vehicles and carriers of the gas which was freely dissolved in the crystalline aggregate. A small percentage of bismuth made most metals brittle, though their individual crystals were perfectly ductile. With regard to iron, the critical temperature came in because below A_1 the iron existed in the alpha form, which was incapable of dissolving carbon. After prolonged exposure to carbon monoxide at temperatures below A_1 there were traces of carburisation along the crystal boundaries.

As regards brittleness, brittle steel was not brittle like cobbler's wax, which was a brittle liquid. All liquids, water in particular, were brittle, hard and strong, shattered by blows and difficult to rupture except by stresses exceeding certain limits depending on temperature. In a brittle crystalline aggregate the viscosity of the intercrystalline cement might have been altered; he had some evidence supporting that. But there was a time factor in the strength of metals, which was subject to the influence of impurities and of physical treatment which affected the intercrystalline cements. From that point of view the effect of gases might be looked for in the reduction of the strength or viscosity of the cement rather than of the crystalline material.

Dr. A. G. P. Gwyer gave further particulars about the experiments on the occlusion of gases by aluminium and its alloys conducted at the National Physical Laboratory. When rolling certain bars into sheets they had noticed exceptional blistering; the gas in the blisters varied much in composition, the volume percentages being: CO_2 4 to 8, CO nil to 9, methane 1 to 24, hydrogen 55 to 81, nitrogen 5 to 11, little oxygen. That aluminium had given much trouble and had to be worked all through to just below the melting-point. The gas figures accorded with those of Sieverts and also those of French workers on aluminium with 3 per cent. of copper, except that the latter observed very high percentages of CO_2, from 7 to 66, in a copper-alloy which was badly corroded by exposure to the atmosphere. In general hydrogen predominated; this was so also in the gases which Guilleman and Delachanel found in tin, bronzes and blistered brass. According to Sieverts the solubility of hydrogen was at a given temperature proportional to the square root of the pressure, and the temperature coefficient was different for the solid and the liquid metals.

Professor C. V. Boys mentioned an experiment of Dr. Percy's which he had himself often watched. When a liquid silver bead was cooled it generally spit and silver was lost; when the cooling was very slow, it did not spit.

A good deal was said about this spitting, notably by Sir Thomas Kirke Rose, of the Royal Mint, who had prepared a paper on "Occlusion by the Noble Metals," but who said that he would not read it because most of his points had already been raised. Referring to Dr. Rosenhain's remarks on gas absorption increasing with a rise of temperature, Sir Thomas said that any such compounds formed, *e.g.*, oxide of silver, were endothermic. According to Le Matelier's Law, any change in the factors which determine an equilibrium causes the equilibrium drum to be displaced in such a way as to oppose the effect of the change. The latent heats of fusion and of volatilisation supplied examples. If the temperature of an ordinary exothermic compound were raised, the compound tended to be decomposed; that caused absorption of heat which tended to stop the rise of temperature. In the case of an endothermic compound like silver oxide and a system containing silver and oxygen, a rise of temperature caused the compound to form and so tended to produce an absorption of heat. When the temperature fell the oxygen was, according to Rosenhain's experiments on aluminium, unable to leave the metal until solidification took place, when it escaped all at once. Dr. Rosenhain, Sir Thomas remarked, was perhaps thinking of what occurred when a metal was cast. If hydrogen were passed through molten copper and the metal left until it was quiescent and then cast into an iron mould, there was a tremendous evolution of hydrogen and showers of bright globules of copper came off; that hydrogen must have been absorbed by the copper or have combined with it. If the copper was left in the crucible, however (not cast), that brilliant coruscation of globules was not seen, though there was a slight ebullition. As regards the spitting of silver, that was never seen with slow cooling of the silver in the shut-off furnace. With respect to brittleness, Sir Thomas thought that the cobbler's wax had its analogue in metals. Gold bars were not pure gold, but contained a little lead, sometimes bismuth; that impurity made the metal brittle, unsuitable for rolling. When brittleness was suspected the bar, ready for rolling, was put in a vice and hit with a hammer; if brittle it broke off like a carrot (instead of bending) and such a bar might split to pieces on rolling. There was, however, an intermediate stage; the bar might break off and yet roll down without annealing. Under gradual rolling it extended into a strong thin plate, quite malleable and good for working.

Sir George Beilby commented upon experiments by Rose and others on the influence which hydrogen had on the crystallisation temperature of gold; the absorption of hydrogen might lower the temperature by many degrees, he said. To this Sir Thomas Rose replied that gold was ordinarily melted in a coke furnace or in a gas furnace and cast in air, and had thus opportunity to absorb both hydrogen and oxygen. Gold thus prepared differed in properties from gold cast in hydrogen.

Referring to the general problem Professor H. F. Armstrong, F.R.S., remarked that he regarded dissolution as a chemical phenomenon, and combinations as conclusions which were complete only under particular temperature conditions. Silver dissolved oxygen because it formed at high temperature some oxide otherwise unknown; when the temperature had fallen to a certain point, modification and spitting began. It was not a mere decomposition but an interaction leading to the formation of different molecular forms of oxygen and of silver. Most gas occlusions of metals seemed to be of that nature. In the case of iron there might further be a greater affinity of CO for iron at higher than at lower temperature. The resolution of alcohol into aldehyde under the influence of copper was another instance of interaction. Mr. E. H. Rayner suggested that the oxygen squeezed out because the molecules of silver had, at low temperature, a greater tendency to combine with one another than with oxygen; it was not because the silver oxide became unstable in the solid, but the phenomenon was due to the silver. Professor Armstrong accepted this suggestion.

Dr. R. E. Slade demonstrated by the aid of diagrams that the sudden liberation of gas from silver, even with slow cooling, was in accordance with the cooling curves of silver and silver oxide.

Dr. J. A. Harker referred to the influence of occluded oxygen on the melting of silver. This was one of the most marked cases, and the phenomena were perfectly definite. If a considerable mass of silver were melted in a reducing atmosphere and the cooling curve determined under favourable conditions in an electrically-heated furnace, it was possible easily to prolong the time of freezing to 15 minutes or 30 minutes, and during the whole of this period the temperature might not change as much as one-tenth of a degree. But if oxygen were present, such as was the case when the silver had been previously melted in an oxidising atmosphere, the halt on the cooling curve was much less pronounced and the freezing began at a temperature about 6 deg. lower than when the metal was completely reduced. The eutectic in this case, probably a solution of one of the oxides of silver in silver froze at about 955 deg.

Dr. Harker had also observed a very marked effect of occluded gas in the melting of iridium. When a strip of iridium was heated in an indifferent atmosphere to its melting-point by low-voltage alternating current, at temperatures from 1,500 deg. C. upwards, negatively charged particles in rapidly increasing number were emitted from its surface, and at the melting-point under high magnification, the phenomena presented were very remarkable; the surface of the metal, though

* *Zeitschrift für Elektrochemie*, 1910, p. 707 to 713

remaining bright and polished, showed all the phenomena of a kind of volcanic eruption, violent evolution of gas taking place and escaping through miniature craters distributed over the surface. The matter emitted was negatively charged and the evolution of gas was accompanied by a very large increase in the negative emission.

Dr. Aitchison mentioned several observations of his which seemed to be incompatible with the suggestion of the formation of intercrystalline compounds. When he put a piece of grooved, carefully machined steel inside a steel tube and submitted it to cementation, the cementation would be perfect in some parts, but not in others, and he did not understand how the CO, which reacted in some parts, came out as such in others; was it supposed to pass through the intercrystalline cement as through a filter? Further, in carburisation the addition of very little ammonia (half a per cent.) increased the rate of absorption of CO more than twenty-fold. Both these observations did not accord with any partial pressure theory (Mr. Johns), nor did the fact that in pickling the maximum effect was obtained with the most diluted acid. It was also peculiar that one could pickle steel in acid both as kathode or as anode, the deleterious gas-absorption effect being the same also in an alkali bath.

Mr. C. R. Darling mentioned some interesting experiments of the American Electric Welding Committee, in conjunction with which a committee over here was now working, he stated. When welding iron with the arc, the iron being the negative terminal, the weld was defective if the iron had previously been pickled in acid, but sound, if pickled in alkali; the arc heating thus did not change peculiarities due to the pickling. Under certain conditions nitrogen was absorbed during the welding, probably as nitride (Desch), and the weakness of the weld had generally been ascribed to the nitride; but the committee had found that welds rich in nitride might be strong. Considering the high temperature of the arc, it was difficult to imagine how the nitrogen got into the iron. When sulphur was present in iron plates to be welded, the metal was seen to boil and froth; the nature of the escaping gas was not established yet, but the weld was unsound, whilst sulphur in the arc electrode did not seem to matter. Mr. Darling further related that during his thermoelectric experiments (brought before the Physical Society) he had noticed that antimony, the true boiling-point of which was near 1,400 deg. C., began to boil already about 800 deg. C., giving off a tremendous amount of gas; he had found that with antimony from various sources.

Dr. H. C. Greenwood referred to the formation of blisters on iron. Sometimes the blisters contained hydrogen. When iron was heated in nitrogen at high pressure (1 ton per square inch) he had noticed that large blisters developed. Ordinary (impure) silver produced blisters when cooled in a reducing atmosphere, owing to the presence of cuprous oxide in the silver. As regards pickling in alkali, Stromeyer had recently found that steel heated in strong caustic soda near 100 deg. or 200 deg. C. had its strength increased, whilst the impact figure was considerably reduced; the action was confined to a certain depth of penetration.

Dr. Wilsmore questioned the statement that the solubility of gases generally decreased with rise of temperature. That seemed to hold only for water; but solubility data were scanty, and water was not a normal liquid. The decrease in solubility seemed to be due to the well-known change in the molecular structure of water, which could exist as hydrol (H_2O), dihydrol and trihydrol. That might have a bearing on the solubility of substances in water. Other substances (organic, *e.g.*) generally became better solvents at higher temperature, and silver, dissolving more oxygen at higher than at lower temperature, seemed to follow their analogy.

The contribution by Dr. H. A. Bumstead, who had come over from the United States, referred to surface films and to the action of so-called δ-rays on them; we dealt with these researches of Dr. Bumstead on page 531 *ante*.

Both Dr. Taylor, who gave instances of the contradictory results of various observers, and Mr. Cosmo Johns, who suggested that experiments should be made on occlusion by strained and by unstrained metals, and that further experiments on pure metals, not industrial metals, were needed, raised a very important point, upon which Dr. H. Borns further dwelt in a brief contribution. The whole experimental basis of the problem is unsatisfactory, he pointed out, and if a committee were to be appointed, it might deal with the experimental methods in the first instance. The various observers diverge widely, quantitatively and qualitatively, the determinations both of occlusion and of liberation of gas are exceedingly difficult, because influences of the gases given off and absorbed by parts of the apparatus not actually under test, can hardly be excluded, and the information given as to methods of determination, gas pressure and temperatures and analytical methods is mostly insufficient. J. E. Johnson and L. Selmi suggested in 1916 that foundry iron was made stronger by the presence of oxygen; how they determined the fractional percentages of oxygen was not clear. The method of Ledebur—the only one available for this purpose—was recently improved by Oberhoffer,* but was hardly reliable yet. The determination of occlusion was mostly made by heating the specimen in a vacuum. In order to avoid contamination of the substance by chemical reaction with the furnace-material, W. Austin tried, in 1912 direct electric heating and fusing by passing the current through the specimen rod, forming the axis of a steel cylinder; he found little gas and some of that might possibly have come from the cylinder which was heated by radiation. There was the further difficulty of gas evolution from the leads. In their most recent experiments G. Alleman and C. J. Darlington,† of Pennsylvania, therefore, returned to electric heating up to 1,900 deg. C. in quartz or alundum tubes, the specimen being placed in a boat of quartz or platinum. The gases were drawn off by a mercury pump, while the wide jacket surrounding the tube was joined to a molecular pump. The many ferrous metals they tried gave off gases (up to 200 volumes) in the order hydrogen, carbon monoxide, nitrogen (last); whether oxygen was present as such or formed by reaction, was left undecided; there was some chemical reaction with the boat. They gave no information as to their method of analysis, but recorded some curious observations. It is known to wire-glass makers that the iron wires become covered with gas bubbles in the melting glass. This Alleman and Darlington observed with iron wire, but not with nickel wire. Yet when they wound a quartz tube with nickel tape and sent the current through the nickel, they found on the inside wall of the tube (which was empty) a spiral black deposit corresponding to the tape convolutions outside, as if some CO or CO_2 had been driven from the nickel through the hot quartz and been decomposed.

Other methods have been used. C. G. Müller, in 1878, drilled the specimen under water or under oil, to avoid any decomposition of water, by the heat of the drilling; he obtained more gas when he used a blunt drill than with a sharp drill; but objections were raised against the method by J. E. Stead and others. There is no method free of objection, and it may not be possible to devise one. If there were, we might learn something about pure metals.

ELGAR SCHOLARSHIP IN NAVAL ARCHITECTURE AND "EARL OF DURHAM" PRIZE.—A scholarship designated the "Elgar Scholarship in Naval Architecture" will be offered for competition among students of the Institution in 1919. All students (being British subjects) who have been elected at or before the annual general meeting of the Institution (April 9, 1919) will be eligible for this scholarship. The scholarship is of the annual value of 100*l.*, and is tenable for three years. A prize of books or instruments to the value of 5*l.*, offered by the Earl of Durham, will be awarded by the council to the candidate next in order of merit to the winner of the scholarship or to such other competitor as, in the opinion of the council, may deserve the award. All communications with respect to the scholarship should be addressed to the Secretary of the Institution of Naval Architects, 5, Adelphi-terrace, London, W.C. 2.

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* See ENGINEERING, May 18, 1917, page 484, and May 17, 1918, page 562, as to Johnson and Oberhoffer.

† *Journal of the Franklin Institute*, February to April, 1918.

NOTICES OF MEETINGS.

UNIVERSITY OF LONDON, UNIVERSITY COLLEGE ENGINEERING SOCIETY.—Friday, November 22, at 5.15 p.m., paper by Mr. E. N. Varian on "Agricultural Machines." Friday, November 29, at 5.15 p.m., paper by Mr. H. S. Kleinberg on "Industrial Reconstruction."

THE PHYSICAL SOCIETY OF LONDON.—Friday, November 22, at 5 p.m., at the Imperial College of Science, Imperial Institute-road, South Kensington, London, S.W. Agenda: (1) "Cohesion" (fifth paper), by Mr. Herbert Chatley, D.Sc.; (2) "Note on the Linguistic Nomenclature of Scientific Writers," by Mr. A. Campbell, B.A.; (3) "A Method of Comparing Tuning Forks of Low Frequency and of Determining their Damping Decrements," by Mr. A. Campbell, B.A.; (4) "A Note on Low-Frequency Microphone Hummers," by Mr. A. Campbell, B.A.; (5) "A Simple Tuning Fork Generator for Sine-wave Alternating Current," by Mr. A. Campbell, B.A.

THE MANCHESTER ASSOCIATION OF ENGINEERS.—Saturday evening, November 23, at the Grand Hotel, Aytoun-street, when a paper entitled "Conveyors in Relation to Engineering Works" will be read by Mr. W. H. Atherton, M.Sc., M.I.Mech.E., Member. The paper will be illustrated by lantern slides. The chair will be taken at 6.30 p.m.

THE JUNIOR INSTITUTION OF ENGINEERS: NORTH-EASTERN SECTION.—Tuesday, November 26, at 7.15 p.m., at the Mining Institute, Neville-street, Newcastle-on-Tyne. Paper on "Boilers, Coal and Gas-Fired," by Messrs. E. F. Oakford and S. H. Moore.

THE INSTITUTION OF ELECTRICAL ENGINEERS: SOUTH MIDLAND CENTRE.—Wednesday, November 27, at 7 p.m., at the University, Edmund-street, Birmingham, when Mr. J. H. Shaw, A.M.I.E.E., will read his paper entitled "High Pressure and High-Temperature Steam in Large Power Stations." Copies of the above paper may be had on application to the hon. secretary.

THE ROYAL SOCIETY OF ARTS.—Wednesday, November 27, at 4.30 p.m., Ordinary meeting: "Drink Control in Various Countries," by Lord d'Abernon, G.C.M.G., chairman Central Control Board (Liquor Traffic). Sir Thomas Barlow, Bart., K.C.V.O., M.D., F.R.S., past-president, Royal College of Physicians, will preside. Thursday, November 28, at 4.30 p.m., Indian Section: "Some Aspects of Hindu Life," by Bhupendranath Basu, Member of the Council of India. The Most Hon. the Marquis of Crewe, K.G., will preside.

THE BIRMINGHAM METALLURGICAL SOCIETY.—Thursday, November 28, at 7 p.m., at the Birmingham Chamber of Commerce, New-street. Paper by Mr. O. W. Ellis, M.Sc., A.M.Inst.C.E. (Chief Metallurgist, Woolwich Arsenal), "The Mechanical Properties of the Alloys of Copper and Zinc as affected by Work."

THE INSTITUTION OF LOCOMOTIVE ENGINEERS.—Saturday, November 30, at 2.30 p.m. prompt, in Room No. 18, Caxton Hall, Westminster, a paper will be read by Mr. John Rickie, Member, London, on "Compound Locomotives and Valve Gears."

THE LATE MR. JOSEPH PEARCE STOCKBRIDGE.—We regret to have to announce the death, which occurred last week at Newcastle-on-Tyne, after a short illness, of Mr. Joseph Pearce Stockbridge. Mr. Stockbridge was born in 1883 and served his apprenticeship course with Messrs. C. A. Parsons and Co., Limited, Heaton Works, Newcastle. He continued in service there until 1910, when he was sent by the firm to Australia, to supervise the complete electric power station equipment of the Adelaide Tramways Commission, for which Messrs. Parsons were the principal contractors. In 1912 he returned to England, and was subsequently entrusted with the management of the firm's Close Works at Gateshead, and continued in that capacity after they were acquired by Sir W. G. Armstrong, Whitworth and Co., Limited, in 1915. Mr. Stockbridge was an Associate Member of the Institution of Electrical Engineers, a member of the North-East Coast Institution of Engineers and Shipbuilders, and of the British Foundrymen's Association.

CHINESE SHIPBUILDING.—According to *The London and China Telegraph*, Shanghai is gradually developing into an important shipbuilding centre. The Nicholas Tsu Engineering and Shipbuilding Works on the Huangpu above the arsenal, a strictly Chinese plant solely owned by Mr. Nicholas Tsu, compradore of the Banque de l'Indo-Chine, is now building two good-sized steel steamers for deep-sea work. While not the largest ships built in Shanghai, being 27 ft. shorter than those of the Solvaer class built for Norwegian owners by the Shanghai Dock and Engineering Company, which has larger vessels on the ways, the sister ships now being built at the Tsu works, which has turned out several steamers for Yangtsze work, will be of approximately 3,500 tons deadweight, and will measure 250 ft. length between perpendiculars (262 ft. overall), 40 ft. beam, and 25·25 ft. depth. Meanwhile, engines are being built also at the Tsu works, and if the boilers arrive from America in time the vessels should be ready for sea at the end of the year. The ships are from the designs of foreign naval architects, and are being built under foreign supervision, but the workmanship—that is, the actual labour—is entirely Chinese. Not only are these ships being built in a Chinese-owned yard that is manufacturing its own engines, but, as a further testimony to the progressiveness of local Chinese, the vessels are to the order of Mr. Ku Din-Tsiang, compradore of the Bank of Chosen.

THE WALLER SYSTEM OF REINFORCED-CONCRETE SHIP CONSTRUCTION.

(*For Description, see Page* 580.)

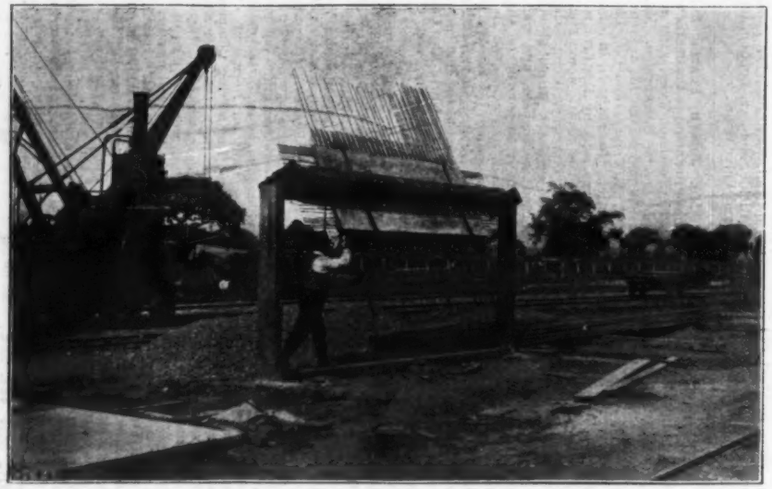


FIG. 12. BENDING REINFORCEMENT BARS ON BOTTOM PLATES.

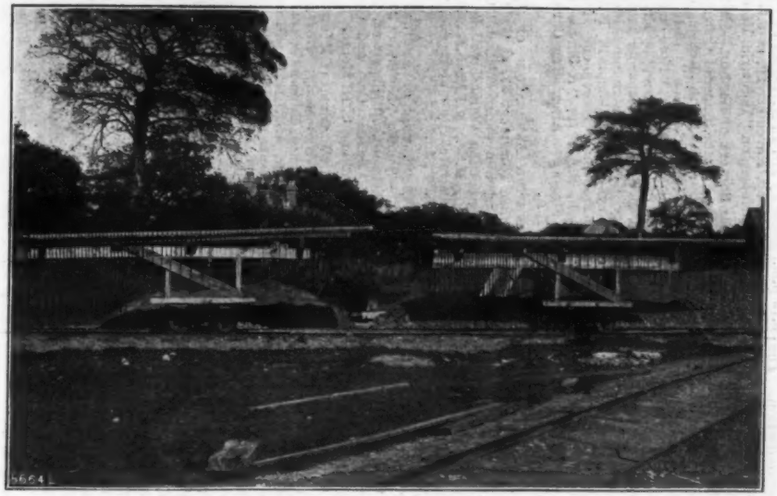


FIG. 13. TRUCKS FOR CONVEYING PRE-CAST PLATES.

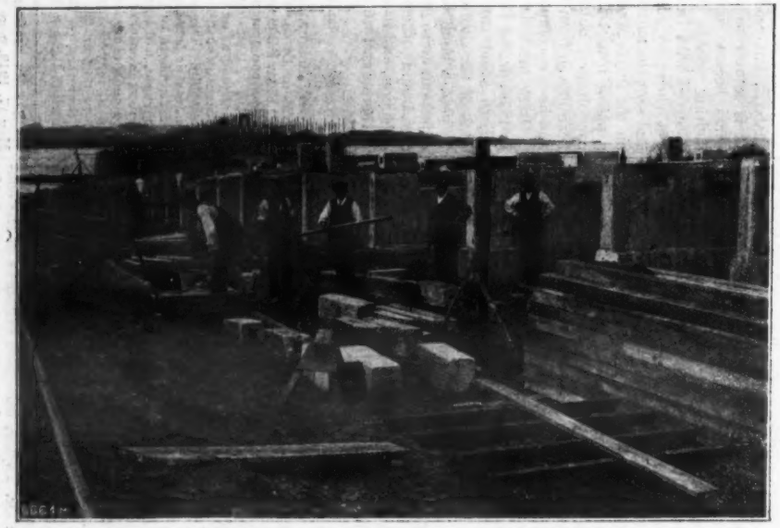


FIG. 14. CONCRETE SLIPWAY WITH SOME BOTTOM PLATES IN POSITION.

FIG. 15. INTERIOR OF BARGE WITH BOTTOM AND SIDE PLATES IN POSITION.

DETAILS OF EXPRESS PASSENGER LOCOMOTIVES FOR THE NEW ZEALAND GOVERNMENT RAILWAYS (3-FT. 6-IN. GAUGE).

CONSTRUCTED AT THE RAILWAY WORKS, ADDINGTON; MR. H. H. JACKSON, CHIEF MECHANICAL ENGINEER.

(For Description, see Page 576.)

Fig. 4. SECTION C.C.C.C.

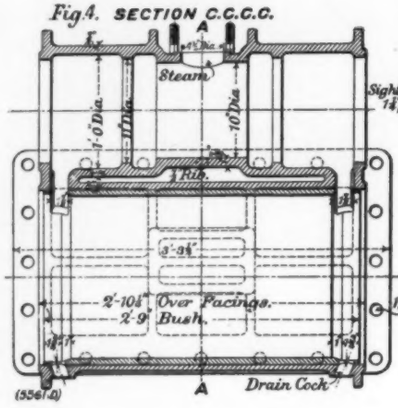
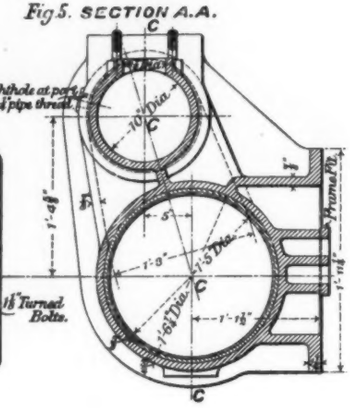


Fig. 5. SECTION A.A.



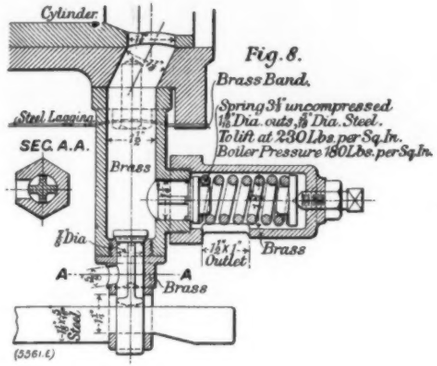


Fig. 8.
Brass Band.
Spring 3½" uncompressed.
1½" Dia. outs. ⅝" Dia. Steel.
To lift at 230 Lbs. per Sq. In.
Boiler Pressure 180 Lbs. per Sq. In.

Fig. 9. OUTSIDE VIEW OF

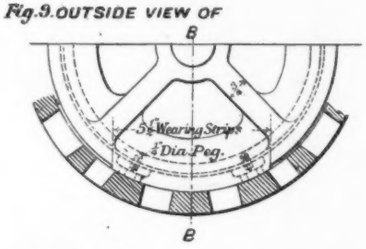
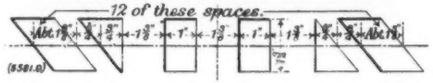


Fig. 12.
DEVELOPED PLAN OF OUTSIDE OF BUSH AT BOTTOM SHOWING STEAM PORT.



SECTION B.B.
Fig. 10.

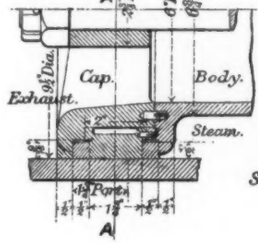


Fig. 11.
SECTION A.A.

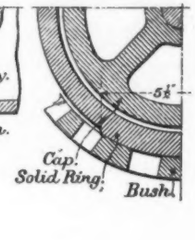


Fig. 6.

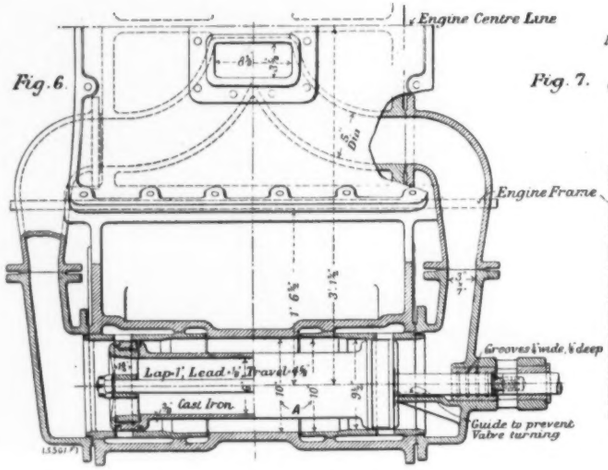


Fig. 7.

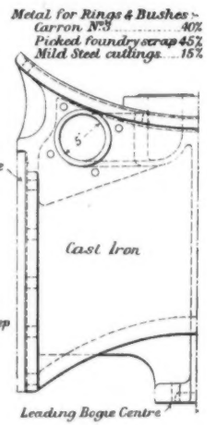
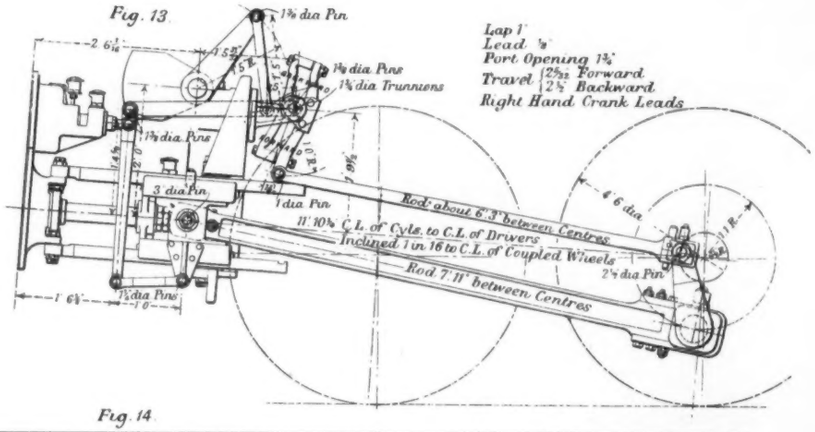


Fig. 13



Lap 1"
Lead ⅛"
Port Opening 1⅜"
Travel 2 5/32" Forward
2⅛" Backward
Right Hand Crank Leads

Fig. 14

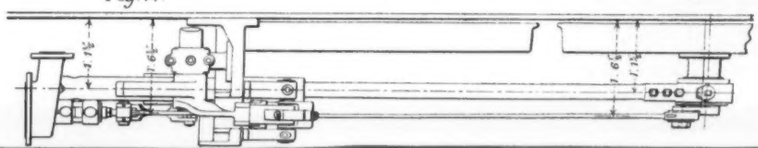
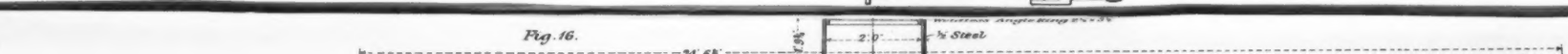


Fig. 16.



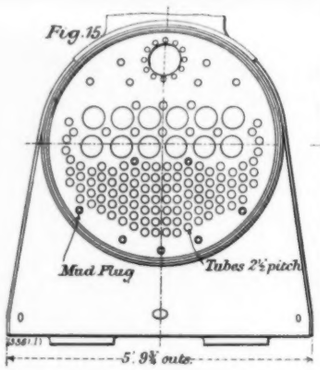


Fig. 15.
Mud Plug
Tubes 2½ pitch
5' 9⅜" outs.

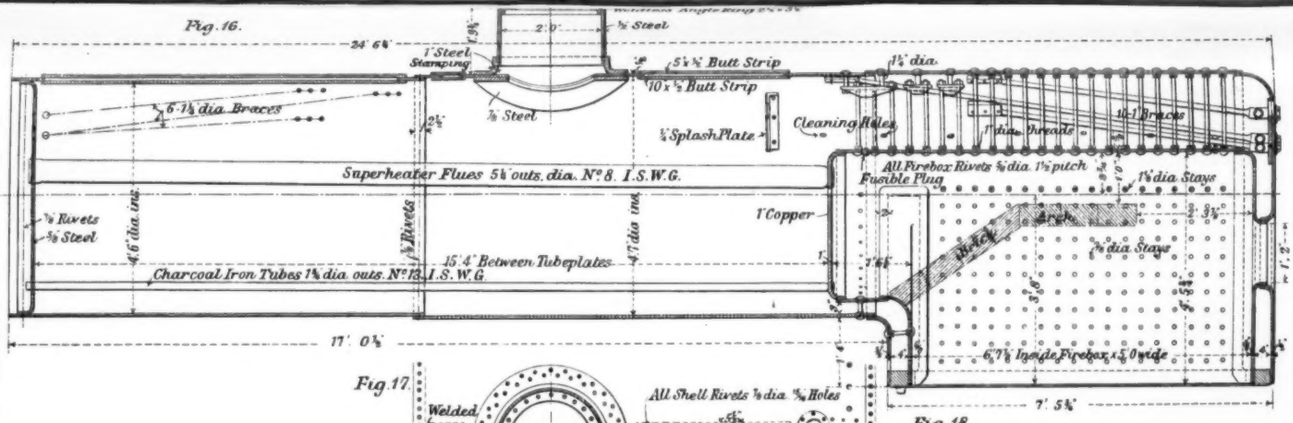


Fig. 16.
24' 6¼"
1' Steel Stamping
2' 0"
½ Steel
5 ¼" Butt Strip
10 x ½ Butt Strip
1½ dia.
6-1⅛ dia. Braces
⅜ Steel
¼ Splash Plate
Cleaning Holes
1" dia. Threads
10-1 Braces
Superheater Flues 5¼ outs. dia. N° 8. I.S.W.G.
All Firebox Rivets ⅝ dia. 1⅝ pitch
Fusible Plug
1¼ dia. Stays
⅞ Rivets
⅝ Steel
4' 6" dia. ins.
⅝ Rivets
4' 7" dia. ins.
1" Copper
Brick
⅞ dia. Stays
15' 4" Between Tubeplates
Charcoal Iron Tubes 1¾ dia. outs. N° 13. I.S.W.G.
17' 0⅞"
6' 7⅛" Inside Firebox x 5' 0" wide
7' 5¾"

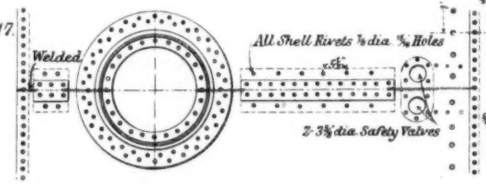


Fig. 17.
Welded
All Shell Rivets ⅞ dia. ¹⁵⁄₁₆ Holes
2-3½ dia. Safety Valves

Fig. 18.

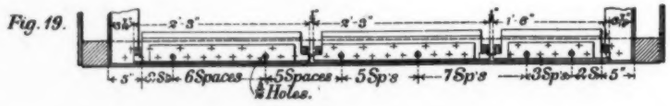


Fig. 19.
2'-3"
2'-3"
1'-6"
5" 2 Sp's 6 Spaces 5 Spaces 5 Sp's 7 Sp's 3 Sp's 2 Sp's 5"
2 Holes.

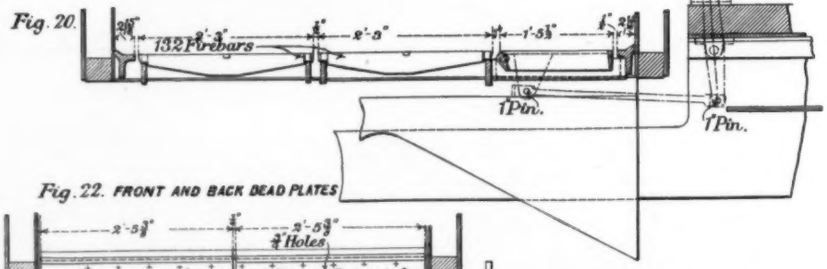


Fig. 20.
132 Firebars
2'-3"
1'-5⅛"
1" Turned Pin.
1" Pin.
1" Pin.

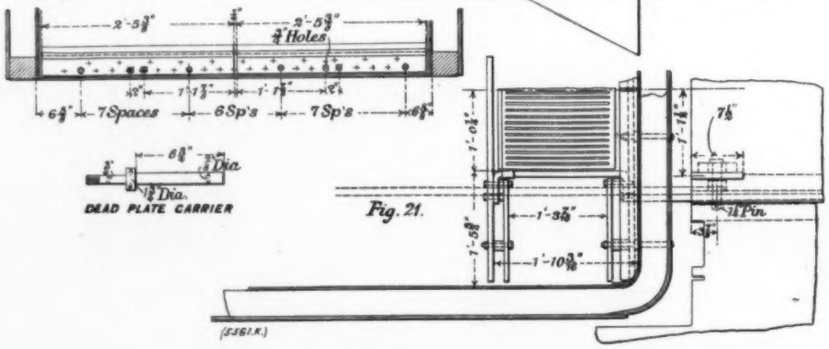


Fig. 22. FRONT AND BACK DEAD PLATES
2'-5⅜"
¾" Holes
6½" 7 Spaces 6 Sp's 7 Sp's
6⅞"
¾" Dia.
1⅛" Dia.
DEAD PLATE CARRIER
Fig. 21.
7⅛"
1" Pin.
1'-3⅞"
1'-10⅜"

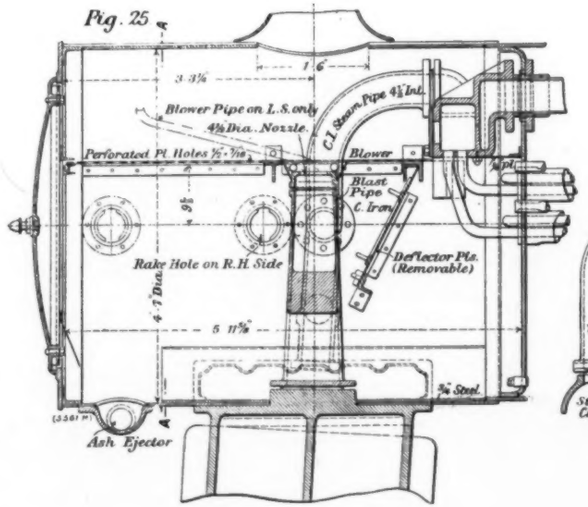


Fig. 25
3' 3⅛"
1' 6"
Blower Pipe on L.S. only
4½ Dia. Nozzle.
C.I. Steam Pipe 4½ Int.
Perforated Pl. Holes ½" - ⅞"
Blower
Blast Pipe C. Iron
Rake Hole on R.H. Side
Deflector Pls. (Removable)
4' 7" Dia.
5' 11⅝"
⅝ Steel
Ash Ejector

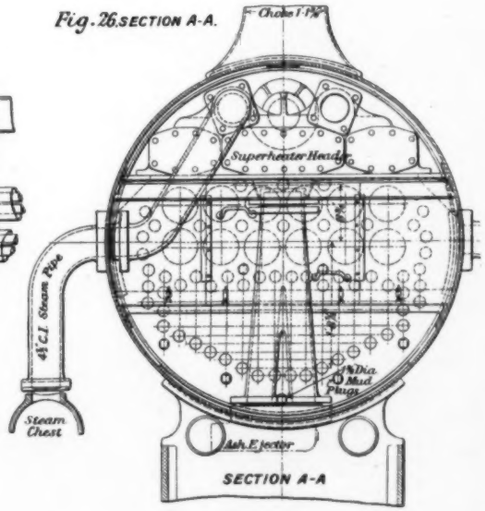


Fig. 26. SECTION A-A.
Choke 1 Pl.
Superheater Header
4½ C.I. Steam Pipe
Steam Chest
¾ Dia. Mud Plugs
Ash Ejector
SECTION A-A

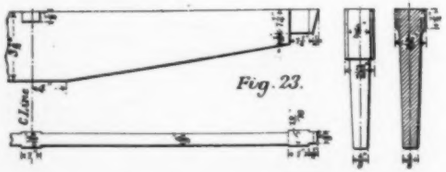
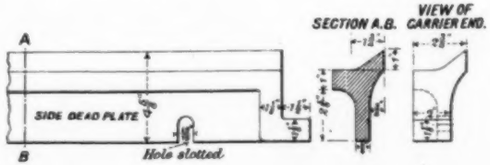


Fig. 23.
C.Line


A
SIDE DEAD PLATE
B
Hole slotted
SECTION A.B.
VIEW OF CARRIER END.

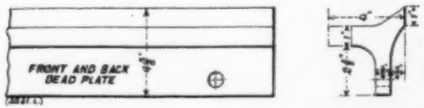


Fig. 24
FRONT AND BACK DEAD PLATE

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NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 585.

ENGINEERING.

FRIDAY, NOVEMBER 22, 1918.

RECONSTRUCTION.

THE Hun has at last learned by proof direct that it may be much more difficult to make Peace than it was to make War. It is to be hoped that as a nation we shall not have a corresponding experience, and that the transition from war conditions to peaceful pursuits will be effected with smoothness and tranquillity. Could we depend upon the maintenance of the spirit which has united all classes of the community during the crisis now happily past, all would be well, but there is a danger that when what Kipling has called "the ties of common funk" are released, the old quarrels will be recommenced. The work before us is stupendous. In view of the enormous cost of the war in human life and suffering there is a natural reluctance to refer to the accompanying dissipation of accumulated capital, but this consideration cannot be safely slighted. We have been expending in the course of a few months the savings of many decades. New wealth must be created and that rapidly, if a reduction in the standard of well-being of the community in general and of the "common people" in particular is to be avoided. We must produce more per head than ever before. Fortunately our recent experiences have shown that this should be easily possible, but the application of this knowledge will involve the scrapping of many strongly persistent prejudices and many hoary traditions. Unhappily, as the debate in the House of Commons last Monday proved, it is not only Bourbons that are incapable of either learning or forgetting, and in the work of reconstruction the nation will have to reckon with the opposition of those whose political and economic views are creeds rather than policies. Fortunately, such devotees are undoubtedly less numerous than they were. Sir Leo Chiozzo Money, it would seem, still cherishes his pristine belief that the whole of the industries of the country can be successfully administered by a bureaucracy and that key industries may safely be sacrificed in the interests of immediate if temporary monetary gains. Others have, however, been much less impervious to the teachings of experience. Some two or three years ago a well-known London evening paper had the temerity to refer to our civil service as the envy of the world, but of late it also has been insistent on the freeing of industry from official leading strings and a reopening of the field of opportunity to that private enterprise which created the wealth that rendered the financing of the war possible.

As Abraham Lincoln once observed, there are certain people that can be fooled all the time, and the all-the-timers still indulge in vast visions of nationalisation of every important industry. It is improbable that any bureaucracy in a democratic country will ever attain the high average of ability which characterised the German general staff. A good average in certain departments of endeavour is, however, as little satisfactory as the good average of Mark Twain's watch, and an English general has asserted that the Hun war machine was a first-class machine run by second-class men. The German general staff throughout the war saw with remarkable clearness the more obvious and immediate bearings of each particular problem that came under their review, but showed unparalleled stupidity in considering matters as a whole. It was for example to Germany's interest that the list of articles recognised as contraband of war should be reduced to a minimum, yet she treated wheat as contraband long before we did, having sunk wheat ships in the Pacific within a few weeks of the outbreak of hostilities. The crass stupidity of the submarine policy, which brought America into the war, requires no emphasis here, and many other equally flagrant instances of lack of insight could be cited. The attempt to conduct the war by our own bureaucracies was soon abandoned, and our success is undoubtedly attributable to the seeking out and securing for the common good the services of those whose ability had been established in the strenuous field of private enterprise.

In his speech last week, Dr. Addison commented on the prejudiced fashion in which Parliament of recent years has dealt with schemes of public utility and expressed the opinion that an alteration was very essential. The House of Commons used to be the worst offender in this regard, but the treatment meted out to the Charing Cross Bridge Bill and the Loch Leven Water Power Bill rather indicates that greater obstruction is now to be feared from the House of Lords. It is generally agreed that a great extension of existing electric power schemes would be of much advantage to the community, but there is strenuous opposition against entrusting the direction and control of these to the only agencies which have successfully dealt with such matters in the past, and a strongly expressed desire to confide this highly important development to politicians whose first anxiety will be not the success of the enterprise but their political careers and to officials whose aim must be to stand well with their political chiefs. Along this line no greater success is to be expected than in the case of municipal tramways, of which, in all probability, not one could pay its way were not legitimate competition prevented by law. Years ago furious opposition was expressed to such a supposed *el dorado* as the Tramways of the Metropolis being opened to a Trust. This opposition succeeded, but long before the war all hope of the promised vast profits from the London County Council Tramways had disappeared, and the undertaking seemed far more likely to prove a liability than an asset. If a similar policy be pursued in regard to national electric power supplies there is little probability of any more favourable issue. Moreover, the delay in getting to work would undoubtedly be serious. A correspondent of the *Westminster Gazette* has pointed out that twenty years ago the House of Commons rejected, after an extremely close division, a Bill promoted by the General Power Distribution Company on the understanding that public authorities were only too ready to occupy the field. Actually nothing was done, and the consequent loss to the nation has, it would appear from the Board of Trade report, been of the order of 100,000,000*l.* per annum.

The Woolwich workmen are demanding that the national shell factories and the like shall remain in operation on peace manufactures. This proposal comes with particularly little justification from Woolwich, as shell makers generally, not only agree that the advice and assistance afforded them by Woolwich was insignificant, but many were so appalled by the general state of affairs there that they freely declared their opinion that the chances of winning the war would be substantially increased were Woolwich and all its works destroyed by Zeppelins. The national factories have, we believe, averaged well, but it is admitted that costs at them have not been as low as in the case of the best of the firms under private direction and control.

It is to be hoped that the extraordinarily detailed information as to the costs of various shop operations which have been accumulated by the Ministry

of Munitions will be rendered available to our industries at large. From prejudices, which being prejudices merely, are particularly difficult to overcome, many of our working classes resent the time and motion studies by which they could be helped to increase their earnings without increasing their efforts. The information collected by the Ministry of Munitions, if made available, might do something to attain the same end, without arousing much opposition.

A large displacement of labour is inevitable, but some of the figures given by Dr. Addison last week and quoted on page 565 of our last issue, are distinctly reassuring. In the chemical trades, for instance, 70 per cent. of the men and 40 per cent. of the women are engaged on work of a kind for which there will be a demand after the war. It must be the business of Parliament to see that this demand is supplied by British firms. In the engineering trades of course the general character of the work will not be altered, although that of the products will. Making all allowances for this, there will nevertheless be nearly a million civilian workers who will have to find fresh occupations. It is proposed to provide a very liberal unemployed benefit to help those thus displaced to tide over the period of reconstruction. Commenting on this plan Mr. Holt very logically pointed out that these munitions workers stand on a different basis to demobilised soldiers. They have been enjoying very high wages and should have had no difficulty in providing for the interval which must necessarily elapse between the shutting down of munitions making and the re-establishment of our peace industries. All this is very true, but to adopt President Cleveland's famous phrase we are confronted with a condition and not with a theory, and it is with this condition that we have to deal. For the most part surplus earnings have not been saved, but have been expended on luxuries. In fact a deputation of women from Woolwich (where fortunes have been accumulated during the past three years in furnishing feminine furs and frilleries) has already demanded a large increase in the very liberal out-of-employment benefit promised by Dr. Addison. This, which is non-contributary, amounts to 24*s.* per week for men and 20*s.* for women, with extra allowances for dependents.

The crisis will be eased by the decision not to cease the manufacture of munitions forthwith. To this course Mr. McKenna has raised the very obvious objection that materials which are badly needed for ordinary peace products will be worked up into munitions for which the demand has come to an end, and he suggested as an alternative that the works should be shut down and the employees given a holiday at full pay. Here, again, however, the matter is less simple than it might appear. Certain imponderables are involved which make it by no means certain that the above alternative would be wise. The weather at this time of the year is far from favourable to a holiday, and we have seen recently in London the tendency of an idle and high-spirited crowd to attempt dangerous diversions which have resulted in damage to certain of our monuments and trophies of war and threatened at times more serious results. It may well be more economical, all things considered, to keep the factories running even at some waste of material.

In addition to the million of civilians for whom new work must be found, occupations must be provided for the four or five million soldiers who will be demobilised shortly. Here, again, there is to be an unemployed benefit which quite properly will be extended over a longer period than in the case of the civilians. The work of finding employment for these millions of men will be to a large extent entrusted to local advisory committees, the members of which will be, in part, representative of employers and in part of the trade unions. Special provision is being made for the younger classes. Many have spent, in defending their country, years which would otherwise have been occupied in acquiring a trade. The Government have decided in their cases that the men shall have the opportunity of completing an apprenticeship. The arrangement is that the employer shall pay during the first twelve months of such appenticeship not less than seven-twelfths of the current rate of wages. This will be supplemented from the Treasury so as to bring up the total receipts to three-quarters of the current rate. In the following year the State will augment its contribution so as to increase the above figure to five-sixths.

The juvenile civilian workers present another problem. In some munition works mere boys have been making 6*l.* or 7*l.* a week. This, of course, cannot continue, and it is moreover most desirable that both the technical and ordinary education of such youths should be resumed. On condition that approved courses of instruction are attended grants of 12*s.* a week in the case of youths between 15 and 18 are to be made, whilst girls will receive 10*s.*

Returning to the Army, it has been decided that for one year from the beginning of demobilisation all permanent appointments in the civil service shall be filled by ex-service men. Moreover, where owing to their military service, officers and men are unable to meet their financial obligations, assistance is to be given, and this may in cases be extended to enable applicants to purchase stock, trade or shop fittings. Assistance will also be given to men and officers whose professional training or university career has been interrupted.

As for plant, many of the national factories will find at least a temporary use as stores. The equipment to be got rid of is valued at a minimum of 500,000,000*l.* sterling, and time will necessarily be required to dispose of so huge a stock without very serious loss.

Within six months free sale in all metals is to be restored. For the present it will be necessary to maintain the steel subsidies, as lacking this, steel makers refuse to give firm prices for their products and manufacturers would be accordingly unable to undertake contracts.

THE INSTITUTION OF MECHANICAL ENGINEERS.

An ordinary general meeting of the above Institution was held on Friday last, the 15th inst., at the Institution of Civil Engineers, Great George-street, Westminster, the president, Mr. Michael Longridge, occupying the chair.

The president first announced the death on the 4th inst., at his London residence, of Sir James W. Restler, a member of council of the Institution. The council had addressed a letter of sympathy to Lady Restler and had expressed their appreciation of Sir James' services. The Institution was represented at the funeral by the president and the secretary.

Continuing, the president stated that the death of nine other members of the Institution had been notified since the last meeting in October, two of whom had given up their lives and the happiness of their nearest and dearest to win the great victories which had brought about a cessation of bloodshed and the hope of a lasting peace, a peace on the part of England without treachery, cruelty or dishonour of any kind.

Mr. Longridge next announced that the council had appointed, subject to his consent, Mr. William Taylor, of Leicester, to fill the vacancy on the council created by the death of Sir James Restler.

The minutes of the previous meeting having been read, the secretary stated that the ballot for election of members showed that 80 candidates had been elected. Nine transferences had been made from the class of associate members to that of full members.

Hardness Testing.

It will be remembered that at the previous general meeting three papers were read and partly discussed. These papers were as follow: "A Law Governing the Resistance to Penetration of Metals when Tested by Impact with a 10-mm. Steel Ball and a New Hardness Scale in Energy Units," by Professor C. A. Edwards, D.Sc., of the University of Manchester, and Mr. F. W. Willis, B.Sc.(Tech.); "The Value of the Indentation Method in the Determination of Hardness," by R. G. C. Batson, of the National Physical Laboratory; and "The Ludwig Hardness Test," by W. Cawthorne Unwin, LL.D., F.R.S., past-president and hon. life member.

Mr. James J. Guest, the first speaker in the resumed discussion, while admitting the claims of Professor Edwards to immediate attention, desired to present his views upon the subject of hardness first. This he did by sketching the stress-strain diagram reproduced in Fig. 1, the curve being distorted for the sake of clearness but generally typical. He then proceeded to sketch, as shown in Fig. 2, a tool penetrating the material, and pointed out that the state of stress in the material would vary throughout, the states of stress at *a*, *b*, *c*, *d*, *e* corresponding in type to those represented at A, B, C, D, E, in Fig. 1, although the stress within the material would be complex. There would be a surface of discontinuity, as marked, through *b*. Outside this surface the material would possess elastic strain energy, within it there would be overstrain, involving lost energy, combined with elastic energy, and in the tool elastic energy only. The tool was supposed to be acted upon by the force P indicated.

A tool of any conical shape, as that sketched, did not involve any linear dimension, and hence in the position shown there was only a single linear dimension involved, which was the diameter *d*, of the indent. Hence, the tool being in equilibrium under the force P and the reaction due to the stress condition in the material, there must be a relationship involving P, *d*, and certain complex stresses and elastic constants of the material, represented under the head *p* in the summation equation:

$$P = \Sigma A d^k p^l \quad . \quad . \quad . \quad . \quad . \quad (1)$$

As throughout *p* was of the dimensions of stress, by dimensional theory the only possible values of the indices were $k=2$ and $l=1$, and therefore P/d^2 must be a constant for the material.

Referring again to Fig. 1, along O, A, B—the Hooke's law portion—the relationship of stress and strain was independent of time, but near and beyond B a time effect showed itself, the curve taking such forms as indicated by the broken line, the metal having a semi-viscous flow. Hence equation (1) would not be quite true and the value of P/d^2 would not be quite independent of the time. But from the known proportions of the phenomena represented typically by such curves it was clear that P/d^2 was the predominant factor in the law of indentation.

Mr. Guest then considered the case of an impact test, Fig. 2 again representing the case of a tool applied with energy E, the corresponding summation equation for the indentation being:

$$E = \Sigma B d^m p^n.$$

The indices again had single values, $m=3$ and $p=1$, so that E/d^3, was necessarily a constant for the material.

Returning again to the stress strain diagram, in which A, B, C, D, E represented a slow test, he pointed out that the effect of a rapid application of the load was to raise the portion of the curve beyond B, as shown by the dotted curves B F, B G. The more rapid the test the higher the curve would be. Drawing D S, F T, G U, perpendicular to the strain axis, for equal amounts of energy communicated to the material at different speeds the areas O B D S, O B F T, O B G U, would be equal. From the known shapes of the curves it was clear that the strains O S, O T, O U, will not differ greatly, and therefore, again, however complex the summation and although some of the energy was spent in vibration and in other ways, the quantity E/d^3, was the main factor in the law sought for.

If at the point G the stress was removed the curve fell along the line G V, the energy measured by the area O B G V being destroyed, but that represented by the area G V U restored by the material. The proportion of energy reaching any element of the material varied; at points such as *a* in the elastic region it was practically all restored, and the proportion of energy restored gradually diminished along *b*, *c*, *d*, *e*. Except for losses—such as due to vibration—the sum of this energy (with that in the tool) appeared in the rebound energy of the hammer, so that the height to which it rebounded duly measured some complex summation determined by the elastic and stress laws of the material.

All the above applied equally whether *d* were taken as the diameter of the indent before or after the tool had left the material.

If the tool instead of being conical—of circular

or other section—were of wedge shape, of indefinitely long edge, then again, there would be no linear dimension involved in the tool and all the above would apply. Such was the tool designed by Professor Unwin, who referred in his paper to the conical tool as due to Ludwik. A cone—and with a truncated point as advocated by Professor Unwin—was in fact used as a tool as early as 1850, so that the name applied should justly be another. The wedge and conical tools had been ingeniously designed to get rid of the length dimension in the tool. In arriving at the above conclusions it was implied that the size of the tool employed should not be that of the internal structure of the material, and hence Professor Unwin's suggestion that a little should be removed from the point of the tool was justified apart from the necessarily small effect.

When, however, a ball was used as a tool its diameter was involved, and with varying depths of impression the similarity of the surfaces of contact between tool and material ceased, as is shown in Fig. 3. If, however, the impressions were of nearly the same magnitude the main factor must still be of dimensions force/length^2.

The magnitudes of the secondary effects were impossible to calculate—perhaps 10 per cent. in the Brinell case, and much less in the others: the direction of the effect in the impact test would be to reduce the diameter of the indent with increase of the velocity of impact.

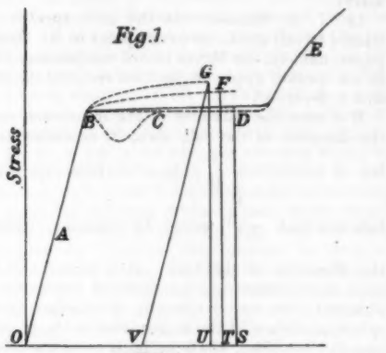
Turning to the paper by Professor Edwards, Mr. Guest considered it to contain a mass of carefully carried-out experiments. The papers presented dealt with indentation hardness alone, but he thought that there was difficulty in determining exactly what that hardness was. The speaker was at first uncertain as to what Professor Edwards understood by hardness. After much experimenting Professor Edwards had arrived at conclusions of great importance, and stated that his method could be "used as an absolute scale for measuring the resistance offered by metals to their penetration by other rigid bodies" and he had also stated that this was a "true measure of the hardness of the metal." The speaker did not approve of the wording used. The definition of a rigid body was one which could not be deformed, wherefore one rigid body could not penetrate another and the statement was a contradiction in terms. Accordingly some latitude should be given when considering the meaning of the wording of the paper.

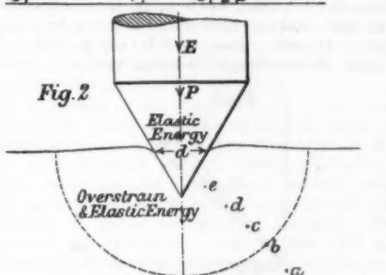
Now absolute scales were of fundamental importance: they must depend only upon the thing measured and be quite independent of the means of measurement employed. The speaker considered that it would be difficult to establish any absolute scale of hardness in view of the differences inherent in the quantities determined by the various modes of measurement.

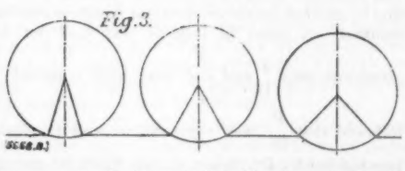
Mr. Guest then proceeded to discuss the six conclusions of the paper, taking the final one first. He remarked that while all hardness measurements were, so to speak, estimations, it was somewhat severe upon the scleroscope that Professor Edwards should use this word with reference to it alone. He held no brief for that instrument, but it did indicate hardness according to the summation previously described. The indentation was small, but that permitted the tests to be made upon the actual parts which were to be used. If the product consisted of hardened parts—particularly if they were case-hardened—it was very convenient to run them over with a scleroscope test. These tests were very rapidly made, because the height to which the little hammer rebounded had to be read as it turned on its journey. Close readings were difficult, but for grading a wide piece of paper was fastened across the scale and it was easily seen whether the hammer appeared above it on the rebound. To judge of the speed of operation, members should watch a girl who was accustomed to the instrument.

The behaviour of the instrument was further criticised, while the Brinell method was also dealt with. The speaker then turned to Professor Edwards' fifth conclusion, which stated that the Brinell scale was not really satisfactory and involved serious errors in all except very hard specimens, and pointed out that the reasoning upon which Professor Edwards based this statement depended upon the shape of the curves of Fig. 8. In this diagram the results of the author's impact tests lay upon a straight line, while the tests by other methods did not.

Mr. Guest then pointed out that there was no horizontal scale to the diagram, and as the Brinell numbers charted ran from 50 to over 600, clearly they referred to quite different materials and there was absolute latitude in placing them on the horizontal scale. If Mr. Brinell or Mr. Shore could interpose in the matter each would choose the abscissæ for the materials differently. To obtain a charted observation at a desired spot it was merely







necessary to select a material of hardness to give the desired ordinate and place it at the desired abscissa. Thus the observations by any method would fall upon a straight line if desired, or if preferred could be arranged to write the name Brinell. He therefore considered that all the criticisms of the Brinell and scleroscope methods as based upon this figure were valueless.

With regard to conclusion (4), which stated that "by using the impact method or scale, the two factors time and degree of deformation—which have different effects with materials of varying hardness—are entirely eliminated," Mr. Guest said that owing to the dissimilarity of impressions of various depths made by one ball some variation was certainly involved, and that he should expect a slightly less diameter of indent with an increased velocity of impact as, owing to the internal friction of the material, the stress-strain curve was bound to rise. There was internal evidence that Professor Edwards' tests had been carefully carried out and they indicated on the whole that this conclusion was true. Taking table No. VI of the paper there were two tests with the same amount of energy—3½ lb. weight with 10-in. drop and 1¾ lb. with 20-in. drop, the former giving the larger indent. This was not the case with all the tests which employed equal energies, but it was so in the greater number. However, the variation was small.

The speaker now referred to the main conclusion, No. 3. The author's statement in the last sentence ran: "In this way a new hardness scale is obtained in inch-pounds impact energy, which is regular throughout its length," which was the absolute scale referred to earlier and in the title of the paper. Mr. Guest took exception to this conclusion. There could be no doubt as to the nature of a quantity measured in inch-pounds energy—it was energy in some form and nothing else. As energy was an objective reality, it could not possibly be a quantity of a material. Energy per unit volume or per unit mass was, but not unqualified energy. That was unthinkable.

Supposing that the scale were in inch-pounds (weight) the word energy being deleted, the quantity measured must have the requisite dimensions (*e.g.*, as the moment of a force had)—but these did not agree with those which it had previously been shown that the main factor required must have. What will-o'-the-wisp had allured Professor Edwards to this treacherous ground? The speaker would investigate.

In the preceding sentence the author had observed that "a much better way is to use the factor for any particular metal and the above equation for calculating the energy of impact required to give an indent of standard dimensions." That was definitely a special case, and Professor Edwards had argued a general law from it—a proceeding quite indefensible scientifically.

In the first sentence of this conclusion (3), the author stated "the factor C is a true measure of the intrinsic hardness of metals"—a phrase which the speaker did not consider justifiable as there were variations in the conception of this hardness, and as the Brinell test was adapted to the softer materials and the scleroscope to hardened, the tests in vogue served useful ends and he did not think that any of them would be abandoned. But they determined, as explained, hardness which varied in conception, though to a secondary extent. In conclusion (2), the origin of the constant C was given, and as it depended upon the fourth root of the energy there was in it no hint of the energy scale which was "uniform throughout its length." "This law, which applied to very soft metals and to hardened tool steel, might be expressed by the equation $d = C E^{.25}$," which was derived from Fig. 5. This equation did not, however, appeal to Mr. Guest, because he could not realise what was expressed by the fourth root of energy. He would therefore proceed to "maltreat" Professor Edwards' equation and make it take successively the forms:

$$\frac{1}{C} = E^{.25}/D \quad \text{and} \quad \frac{1}{C^4} = \frac{E}{d^4} \quad \text{or} \quad k = \frac{E}{d^4}$$

which were equally equations to the curve. Why should the author select C rather than 1/C or k as his particular constant? The speaker preferred the last form as it was realisable mentally, but the new constant had not the dimensions shown to be necessary in the introduction, namely, energy divided by (length)^3, and therefore it was incorrect. Now in the ball impact test there was only one primary dimension, that of the ball, which suggested that the equation should be $L = \frac{E}{d^4} D$ where D was the ball diameter, and L a constant for the material. If such an equation were true, then the term "absolute" as applied to Professor Edwards' constant C, as well as to his energy scale, must be abandoned.

There was no evidence to be gleaned from this paper upon this point because Professor Edwards' experiments dealt with 10-mm. balls only. Mr. Batson, however, had experimented with balls of two diameters, and from his results evidence could be gathered. The speaker had selected the second and third experiments of Table V and the ninth in Table IV, upon mild steel, as these gave an indent diameter of about 2·5 mm., that being the size which Professor Edwards regarded as the most satisfactory. From the data given in these tables the various quantities listed were calculated.

The values of Professor Edwards' constant C for the two experiments with the 10-mm. ball were 4·635 and 4·73, as shewn in the Table overleaf, while its value when the 4·76-mm. ball was employed was 3·76, thus showing that Professor Edwards' C was no absolute constant for the material but was a function of the ball diameter also.

E Energy of Impact.	V Volume of Indent.	d Diameter of Indent.	D Diameter of Ball.	h Depth of Indent.	S Spherical Area.	C Professor Edwards's Constant.	E/S²	E/V
0.054	0.25	2.234	10	0.126	3.97	4.635	0.00343	0.216
0.089	0.45	2.584	10	0.170	5.33	4.73	0.00314	0.198
0.158	0.73	2.376	4.76	0.319	4.77	3.76	0.00697	0.217

Mr. Batson's paper was set out in excellent style and had afforded the speaker much pleasure in the reading. He would like to refer to the author's discussion of someone's rule that the dynamic hardness was to be measured by E/S^2 where E was the applied energy and S the spherical area of indentation. Mr. Batson had compared the values of the measures for the hardness obtained by dividing the applied energy by the volume of indentation V, and by S^2, by plotting the quantities V and S^2 against one another, Fig. 3, calculating from the formulæ, $V = \frac{\pi}{3} h^2 \left(\frac{3}{2} D - h\right)$ and $S^2 = \pi^2 d^2 h^2$, which he gave. Now the elimination of h between these equations could not give a straight line, and the speaker wished the curve had been referred to as nearly straight. Dividing the expressions, it was seen that:

$$\frac{S^2}{V} = \frac{2\pi D^2}{D - 2/3\,h} = 2\pi D\left(1 - \frac{2}{3}\frac{h}{D}\right)^{-1}$$
$$= 2\pi D\left(1 + \frac{2}{3}\frac{h}{D} \cdots\right)$$

so that the departure from straightness was represented by $\frac{2}{3}\frac{h}{D}$, which was 0·067 for the data selected by Mr. Batson and for the experiments given above about 0·01 and 0·045.

It would, however, be noticed that the ratio of S^2 to V depended upon D, so that there was a different "straight" line for each ball diameter. Hence Mr. Batson's conclusion "that both the methods of expressing hardness used by Martel and Roos must be in agreement, for ordinary indentations, when a ball-indenting tool is used" was incorrect. But why, he asked, should Mr. Batson bother at all about Mr. J. O. Roos's formula. It was necessarily wrong, as it was of incorrect dimensions. Mr. Guest now added to the table columns giving the values of E/S^2 and E/V. The former quantities varied from 0·00314 for the 10-mm. ball to 0·00697 for the 4·76-mm. ball, illustrating the dependance of this formula on the ball diameter. The variation of the figures in the column E/V did not suggest dependance upon ball diameter.

Mr. Guest then connected Professor Edwards' constant with the volume of indentation, writing:

$$\frac{d^4}{V} = \frac{32\,D}{\pi}\left(1 - \frac{h}{D}\right)^2\left(1 - \frac{2}{3}\frac{h}{D}\right)^{-1}$$
$$= \frac{32\,D}{\pi}\left(1 - \frac{4}{3}\frac{h}{D} \cdots\right)$$

thus showing that C^{-4} was of the same nature as the expression of Mr. Roos, but with a different coefficient for the term $\frac{h}{D}$. That the values of C tabulated varied less than the values of E/S^2 was due to the glozing over of the effect of the variation of the diameter ratio by taking its fourth root. This, however, simultaneously reduced the whole variation of the constant and hence the gain is illusory.

As $\frac{h}{D}$ was small, there was little difference between E/V, $\frac{E\,D}{S^2}$ and $C^{-4}\,D$. Now the energy summation for the ball impact might, taking h (the permanent indent and D as the involved lengths), be written

$$E = r\,D^3 + S\,D^2 h + t\,D h^2 + u\,h^3$$

since E increased with D and h. Putting $h = 0$, $E_0 = r\,D^3$ was the energy which would just not produce a permanent indent. This had some value, and as it varied with D^3 the ball method was not well adapted to make "absolute" determinations. Since, to a first approximation, $4\,D\,h = d^2$, the above equation might be written

$$E = r\,D^3 + S/4\;D d^2 + t/16\,\frac{d^4}{D}\left(1 + \frac{u}{t}\frac{h}{D}\right)$$

With a given diameter of indent a small ball penetrated further than a large one, and therefore the second term was probably zero. Hence the most important feature must be the third term. The experimental work confirmed this. The above coefficients should form the aim in experimental work.

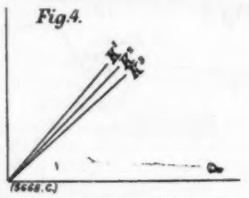
Professor Unwin's wedge and the cone tool avoided these difficulties.

The use of dimensional theory was generally regarded with suspicion, but it was trusted by the speaker. It was a path blazed by truth into Nature's realm; if its occasional gleam encouraged the hesitating traveller he was probably upon the right track—but if it failed, then assuredly he was astray.

Dr. T. E. Stanton was the next speaker. He wished to call attention to one point in Mr. Batson's paper, namely, the Meyer law of comparison, which, in the speaker's opinion, had not received the attention it deserved.

If d were the diameter of the impression and D the diameter of the ball, then, if, according to the law of comparison, $\frac{d}{D} = \kappa_1$ were kept constant, it followed that $\frac{P}{\frac{\pi d^2}{4}}$ would be constant, whatever the diameter of the ball. It followed also that since exact geometrical similarity of impression was obtained, the vexed question of whether to take spherical surface of the indentation or the projected area did not arise, since in both cases the relation between load and area would be given by a straight line. If other values of d/D, say κ_2 and κ_3, were taken the resulting lines would be thus:

Fig.4.



A definite hardness number which was a constant was obtained along each line. In passing from one line to another, however, different hardness numbers resulted. A point of interest was that for any given line since $\frac{d}{D}$ and $\frac{P}{\pi d^2}$ were both constant, it followed that $\frac{P}{D^2}$ was constant, a useful relation pointed out by Dr. Baker at the Sheffield meeting when the paper was discussed there. Dr. Baker had said that in the case of a piece of material so small that the 3,000-kg. load could not be put upon it, in order to obtain the same hardness number it was only necessary to use a smaller ball with a value of P given by the above relation. This would be obvious from the figures since one of the straight lines must correspond with the hardness number given by the standard Brinell test with a 3,000-kg. load and a 10-mm. ball, and along that line $\frac{P}{D^2}$ was constant. The speaker believed Mr. Batson would agree that this was a better method of obtaining the standard Brinell figure than the one given in his paper. Dr. Stanton would suggest to the Hardness Committee that an investigation of this law of comparison should be carried out. It might not be perfectly correct, but it should be very nearly so, since in the discussion at Sheffield Dr. Baker had given a series of results obtained with different materials, using a relation which involved an assumption of the law, and using different sizes of balls, and the hardness numbers were almost identical.

Mr. Thomas W. Chalmers asked Mr. Batson whether he was quite satisfied that the figures given in Table II of his paper really confirmed the conclusions reached. In the last column of that table the author had given the formula for the hardness number corrected to 10-mm. ball (Brinell), and the table seemed to suggest that those figures might be compared with the figures given in the fifth column. These figures should also be corrected by Moore's formula. In the case of the high carbon steel, Mr. Batson suggested, on the face of it, the application of the formula, because with the 10-mm. ball the Brinell figure was 236, while in the case of the 4·76-mm. ball the Brinell figure was 225 corrected to 235, showing a discrepancy as between the two tests of only one. If the Moore formula were applied to the 10-mm. ball figure the result would be 244, which would compare with the 235 of the 4·76-mm. ball figure. It would seem, therefore, that Mr. Batson had compared a corrected with an uncorrected figure, the resulting discrepancy being 8. With both figures corrected he would get a correction of 8.

Mr. L. Pendred suggested that the question of similarity might be overcome if, instead of measuring the depth or diameter of the indentation, the indentation were made constant; if, for example, the load were placed upon a ball of any selected diameter and the rate of indentation into the material were measured. An indentation of one-thousandth or of two-thousandths of an inch might be taken as a standard, using a 10-mm. ball, the measure then being the variation of load instead of the variation in the diameter or depth of indentation. In this manner the whole difficulty attaching to the form of indentation and geometrical similarity would be entirely overcome.

Mr. H. L. Heathcote referred to Mr. Guest's remarks. Mr. Guest, he said, had written it down that the energy of the blow was equal to the sum of certain energies on the other side—the elastic energy in the denting tool and the elastic energy in the specimen, plus strain energy. The speaker thought that the energy required to move the metal should also be taken into account. If integrations were taken up to the time when the depression was completed, the total energy of the punch had the effect not only of developing the strain energy in various forms in the specimen, but also of moving the metal out with a certain velocity; that metal had a certain mass which should be taken into account. Perhaps Mr. Guest would consider that point. Reference had also been made to the differences in the indentation produced by the impact test and by the static test. When experimenting with the punch referred to by Mr. Batson, and applying the curve showing the relation between diameter and depression produced and the Brinell numbers, the speaker had not obtained a curve exactly parallel with the curve showing the Brinell diameter as a function of the hardness; both were sloping curves, but one curve crossed the other in two places. The speaker had available a curve showing the relation between the auto-punch diameter and the Brinell hardness, but time did not permit him to sketch it on the blackboard. The effect of the crossing of the curves was interesting, and suggested that the hardness, as found with the auto-punch, of a hard specimen was greater and of a soft specimen less, than would be found in the case of the Brinell test. The Brinell test hardened the specimen, but according to his experience it hardened it less than the auto-punch test. He had not been prepared for the crossing of the lines at the hardness end and his explanation was that the Brinell test crushed a hard specimen, disintegrating the metal, and that the impact test got its work done before the crushing and softening had taken place.

Mr. R. G. C. Batson then replied to the discussion so far as it concerned his paper. Sir Robert Hadfield, he remarked, had expressed a hope that nothing would disturb the Brinell test. All would agree that the Brinell test was so widely known and used in engineering works that, from practical considerations, any deviation from that test should be greatly criticised before being accepted. Moreover, any variation of method adopted should be capable of conversion into Brinell numbers, if necessary. With regard to similarity of indentation, all work in this connection went back to Meyer, who showed that the formula $\frac{P}{\pi d^2}$, load over area, was constant for the same material, for the same ratio of d to D. Moore's formula, as Dr. Unwin had pointed out, was also based on similarity. It reduced the hardness numbers of all materials to that which would be calculated from the load

which gave identical impressions. It was calculated to the same impression for other materials. The numbers would not necessarily be the same as those derived from the standard Brinell method. For softer materials, such as those with which the speaker had experimented, it would give numbers which were approximately the same. Probably that method of applying the similarity law was not so good as that of Dr. Baker, because by the latter method the material was taken independently. Dr. Baker assumed the Brinell standard for the material and, by means of a modification of Meyer's formula, applied that to that one material alone. The speaker's reason for forming that conclusion was that the extrusion of different materials varied in form. At the previous discussion, Mr. Main had referred to the time effect. Personally he had found that, in the Brinell hardness test, any time effect was most marked up to about 10 seconds application of load, being subsequently very small. Dr. Unwin had directed the speaker's attention to the inertia effect of the machine. If, in the Brinell test, the load were too rapidly applied, the errors due to inertia effect were far greater than those attributable to any time effect. For this reason, when making an accurate standard Brinell test, the speaker used a testing machine with compression plates, the ball being in the holder between the plates. The ball was placed over the specimen, and the load applied was about one-sixth of the final load to be employed. The load was very slowly applied, a little faster at the start, but very slowly as maximum load was neared; the load was then left for about 60 seconds. The speaker submitted the following figures of an experiment with mild steel. With a load of 3,000 kg. applied for 2 seconds the indentation was 5·45; for 3 seconds, 5·48; for 5 seconds, 5·49; for 15 seconds, 5·49; for 50 seconds, 5·50; and for 60 seconds, 5·50. With the full load of 3,000 kg. put straight on to the test-piece without any preliminary slow running, and kept on for 60 seconds, he obtained a figure of 5·53, showing the error due to inertia almost as big as the error due to variation in the application of the load between 2 seconds and 15 seconds. He could not agree with Dr. Unwin's view that the load, in the case of a ball test, was proportional to the area. Meyer found, in his well-known researches, that the pressure equalled constant times diameter to the n where n was variable; if the load were proportional n would not be variable. Professor Edwards had given a table showing that with varying load the hardness number altered, and certain figures in the speaker's paper showed the same effect.

Turning to the dynamic side of the testing, Dr. Edwards had submitted a formula which, as Mr. Guest had shown, could be just as well expressed as $\frac{E}{D^4}$. Roos had proposed energy over area squared, both formulas being in the same direction. Martell's formula was energy over volume. The speaker, in his paper, had shown that, for the ordinary indentations met with in practice, both formulas would give an identical sequence of numbers for the materials tested—both Roos' and Martell's formulas. In the same way, it could be shown that if volume were plotted against diameter to the fourth a nearly straight line would be produced, with only a slight upward curve. So nearly straight was it that the errors would not, in the majority of cases, be more than the errors of observation. Taking D^4, spherical area squared, the D^4 would depend on the flat diameter, and a slightly curved line would be expected. In the case of Dr. Edwards' formula, assuming the relationship of volume to be correct, it would be expected that with higher energies his constant C would be slightly lower than in the case of lower energies. The speaker believed that Dr. Edwards had, in a recent paper, indicated that such was the case with the soft materials he had tested.

Dr. Edwards had not shown in the paper under discussion that tin was at all abnormal, but had done so in a recent paper, a fact also borne out by the results shown on the wall diagram. The speaker would ask Dr. Edwards if the tin used was pure or whether there was any reason for the deviation in the case of the earlier paper. At the previous general meeting the speaker had pointed out that the relationship between dynamical and static impact gave a fairly constant number when the dynamic number was calculated from the net energy of the hammer. He had worked out some of Dr. Edwards' figures and found that the numbers increased, and he thought that circumstance might be due to friction in the slides or elasticity in the supports. Mr. Batson here exhibited a lantern slide of the machine he used for impact testing, from which it could be seen that there was a fairly substantial base to the machine, which was bolted to a very heavy concrete foundation.

Dr. Unwin had spoken of the effect of the rebound, stating that Martell had arranged his drop so that the effect of the rebound was invariable. Experiments, Mr. Batson said, indicated that the amount of the rebound was proportional to the striking energy, so that the percentage effect of the rebound on the results would be the same whatever the striking energy. With a small striking energy the rebound would be small, and the percentage effect would be the same as with a large striking energy, as in the latter case the rebound would be only proportionately larger.

With regard to the volumes of indentation being the same for different forms of tool, those results in the paper which included the rebound were calculated by allowing the hammer to drop at different places along the material, and summing up the total volumes of the indentations. The speaker had since carried out numerous tests by measuring the rebound, taking the striking energy and energy of rebound and dividing by the volume of the first indentation, and had found, with the cone test, that the volumes given in his paper were between those which would be obtained by taking the striking energy and the net energy.

In the course of the discussion at the previous meeting, Mr. Heathcote referred to the radius of indentation as much larger than the radius of the ball. In relation to this, Mr. Batson exhibited a lantern slide showing indentations carefully measured on a milling machine with a depth indicator measuring to ten-thousandths of an inch. The results in this case agreed more or less with Mr. Heathcote's experience; there was an appreciable divergence between the radius of curvature of the impression and the diameter of the ball. Another peculiar fact in connection with the cone test was this, that in the case of certain steels the material poured upwards round the sides; with a manganese steel the material went downwards. That showed that strict similarity in impression with different of material could not be obtained.

Dr. W. C. Unwin said he was glad that, some little time ago he had disinterred Martell's papers because he had seen no papers on hardness which threw more light on the indentation test. The two papers, taken together, were very scientifically expressed, and Martell had treated in succession all the variables—speed, &c.—with which he had had to deal. Mr. Batson had disagreed with the speaker that pressure was proportional to area. In that the speaker had followed Martell. Martell had made some practical load experiments in which automatically he had drawn a stress-strain diagram while the test was going on, and had found the stress to be proportional to the indentation at all stages of the indentation. Martell, of course, was not infallible, but the experiment was a difficult one, and some attention should be paid to the results. With regard to the impact test and the statical or gradual-loading test, results clearly showed a difference betwen the two. Mr. Batson had stated the hardness ratio as between the two kinds of test at 1·5. Martell found that, on the average of experiments, the variation was 1·25, an important difference. The speaker was still disposed to think that the difference was mainly an effect of time. Mr. Main had mentioned experiments on time-effect, made by him, in which the time effect, appeared to be very small. These experiments however, had not extended over any great range of time. Moreover, Dr. Unwin had grave doubts whether the expeerimnts were so easy to make as Mr. Main had suggested. Indeed, he felt sure that in carrying out such tests—especially the Brinell test—very rapidly there would be considerable inertia effect. The point was of importance because so many hardness tests had to be carried out very rapidly. Some while ago Dr. Unwin had quoted some tests by Guillery, in which the latter found considerable time effect. In one material, with a gradual loading (he believed in a second) there was 8 per cent., and in another material there was a difference of 14½ per cent. Guillery seemed to have appreciated the importance of inertia effect, because he had invented a new testing machine in order to work the test. Instead of using a machine in which the moment of loading was fixed by the rising of a ball against a deadweight, he applied the load by springs, so that the inertia effect was nearly or entirely got rid of. The effect of any inertia in the descending load was to increase the indentation and to neutralise the time effect; that was to say, if there were inertia in rapid loading an indentation would be obtained which was as large as that obtained from a very slow, gradual loading. In conclusion, he would remark that two metals would never quite agree. He had already said two or three times when discussing the subject, in ENGINEERING and elsewhere, that there were several secondary causes which affected the indentation, such as the flattening of the Brinell ball, the rising of the edges of the Brinell indentation, and, in the case of the impact test, the waste work due to vibrations, &c. Subject to those remarks, he thought the impact test and the gradual loading test were really the same test. Allowing for the secondary causes, especially for the time effect, the two tests would, he believed, give the same result.

The president then closed the proceedings, observing that Mr. Heaton's paper on "Electric Welding," which it had been intended to read that evening had time permitted, would have to be deferred until the next general meeting.

NOTES.

Science and the Future.

On Wednesday evening, Mr. Alan A. Campbell Swinton, F.R.S., who has been elected chairman of the Royal Society of Arts for a second term of office, delivered an address on the occasion of the opening of the new session. Last year he spoke on Science and its Functions; this year on Science and the Future. Naturally the subject was very wide—far beyond what we can deal with adequately this week—and all that we can do is to mention a few of the salient points. Mr. Swinton, in speaking of the effects of the war, reminded his hearers that a great part of the capital, or the wealth, of the world is indestructible. Gold and silver, bricks and mortar, railways, ships and machinery all fall into decay in process of time. Scientific knowledge, on the contrary, once gained is everlasting. If all our material possessions were swept away we should not relapse into the savage state of our ancestors. To reconstruct the material things would take only a small fraction of the labour and time expended in learning how to create them. Our greatest asset is the vast store of knowledge that Science has gathered together, and this cannot be destroyed by explosives. The capital of the world is mainly due to the mental efforts of exceptional men who, through countless generations, by their investigations, discoveries and inventions have rendered possible all our wonderful possessions. The war has shown us how little margin we have in the way of food, and if the population of the globe should continue to increase at the present rate a very few hundred years might cause the demand for food to exceed the supply, unless new achievements in the way of scientific discovery and invention and more scientific organisation enable us to produce food more easily and abundantly than at present. If science is to play a greater part than it has done in the past the knowledge of it must be widespread. It must be inculcated as a part of general education. In the past, science was largely advanced by men who were self-taught, but it is daily becoming more abstruse and more difficult to acquire. Many men who might have become eminent in science failed to do so because of the initial difficulties. In the cases in which great success was attained it is often possible to find some seemingly accidental circumstance which

turned men into scientific pursuits. But if science is to be the great factor of the future every youth must be taught enough to enable him to go forward to greater things if the bent of his mind inclines that way. Mr. Swinton discussed the question whether knowledge was better advanced by men working under the stimulus of poverty or with the advantages that attend competence or wealth. He adduced numerous instances on both sides, and summed the matter up by saying: "Some temperaments require the spur of necessity to make them exert themselves, while for others the grinding task of providing daily sustenance for themselves and their families suffices to exhaust their energies and leaves nothing for other endeavour." Turning to the future of science, Mr. Swinton pointed out that it is illimitable. Every new discovery and invention opens the path to others, and thus the scientific horizon widens year by year. In the comparatively new fields of radioactivity, electromagnetic radiations, synthetic chemistry, chemical catalysis, electrical osmosis, photo-electricity, and corpuscular matter, to mention at random only a few, the prospect seems practically illimitable.

The Röntgen Society.

Taking advantage of the coming of age of the Röntgen Society, Mr. G. B. Batten, M.D., C.M., in delivering his presidential address, dwelt on some reminiscences of the early days of the society and of his own electrical experience. He had been present when the first lecture on the telephone was given before the British Association at Plymouth, in 1877. At the end of that lecture, Dr. Batten related, Sir William Thomson was asked to speak through the telephone; Thomson's words were: "Hey, diddle, diddle, the cat and the fiddle, go on with that," and presently he cried out, fairly jumping with joy: "I heard them say: the cow jumped over the moon." Years afterwards Dr. Batten was informed by Sir William Preece, who had been at the other end of the telepone, that they had heard nothing, had said nothing, and that Lord Kelvin heard nothing. Kelvin could be enthusiastic; whether his enthusiasm enabled him to hear what he was waiting for, or whether somebody's memory is at fault, it is too late probably to settle; but we are afraid the story, like so many others, cannot claim to be history. Dr. Batten naturally deals chiefly with the biological effects of X-rays. The union of physicists, medical men and instrument makers in the Röntgen Society, has no doubt been highly beneficial to the society and to the public. But Dr. Batten mentioned that a new British Association of Radiology and Physicotherapy—there was already a similar institution—has been formed under auspices of Dr. R. Knox, the senior honorary secretary of the Röntgen Society. Heat and light, ultraviolet rays, quartz mercury lamps and tungsten arcs, and X-rays and gamma radiations were now therapeutically utilised. The two latter in particular, it was believed, stimulated the growth of cells and living organisms in small doses; larger doses retarded, still larger destroyed and killed the cells. Dr. Batten demonstrated this years ago with mustard seed, fish ova, fresh-water snails, &c. X-rays would destroy cancerous growth when lying not more than ½ in. below the surface; most malignant growths were deeper, and the deeper layers might hence be stimulated by the treatment; Dr. Batten therefore recommended excision followed by X-ray treatment for at least two years. Radium radiations were preferred for local treatment at spots little accessible to X-rays. The effects of X-rays were not immediate. In ringworm, one of Dr. Batten's own specialities, hair began to fall out after a fortnight or later, and he suggested that the ringworm fungus and spores were ejected at the same time, thus curing the disease; but in his 3,000 cases he had had only one case of ensuing permanent baldness. X-ray bulbs, he thought, might further be improved, possibly if the comparatively long interval between the effective impulses were utilised; that might be attained with the aid of continuous current generators for 120,000 volts. Some day, however, radiations from radioactive substances might supersede X-ray apparatus. In his concluding remarks Dr. Batten referred to the mystery of life and to an immortal soul. If life were merely a form of energy in the monistic sense, immanent in matter from the beginning in the minute aggregations of moving electrons, themselves atoms of matter, then the living energy should either die with the cell, or should be transformed into some other form of energy. There was no evidence of any such transformation. Life was not electricity, nor was electricity life in any sense. Life must be something apart from electrons, atoms, and something apart also from the material universe, a separate creation. But life controlled certain reactions, and X-rays possibly acted by modifying the movement of the electrons within the atoms of the cell.

INDUSTRIAL NOTES.

The director of the Department of Labour Statistics, writing in *The Labour Gazette*, states that in October employment remained very good in most industries, and much overtime was worked. In the textile industries, however, apart from the woollen and worsted trades which were busy, employment generally was only fair.

Trade unions, with a net membership of 1,146,851, excluding those serving with the forces, reported 0·4 per cent. of their members as unemployed at the end of October, as compared with 0·5 per cent. at the end of September and 1·1 per cent. a year ago.

Of the 3,686,556 male and female workpeople insured under the National Insurance Acts of 1911 and 1916, the number unemployed at the end of October was 24,505 (or 0·66 per cent.), compared with 0·67 per cent. in the previous month, and 0·78 per cent. a year ago. For males and females separately the percentages unemployed at the end of October were 0·31 and 1·59.

The average weekly number of vacancies notified to all Employment Exchanges for the five weeks ended October 11, 1918, was 40,266, as compared with 42,627 in the previous four weeks, and with 38,097 in the five weeks ended October 12, 1917. The average weekly number of vacancies filled for the same period was 30,697, 33,373 and 28,477 respectively. The number of workpeople remaining on the live register at October 12, 1918, was 27,125 men, 51,149 women, 7,462 boys and 7,691 girls—a total of 93,427.

The changes in rates of wages (including war bonuses) reported to the department as having been granted in October resulted in an aggregate increase of about 100,000*l.* in the weekly wages of over 500,000 workpeople. No decreases were reported.

The principal changes recorded were increases awarded to dock labourers at all the large ports, usually amounting to 1½*d.* per hour, and bringing the total war wage advance in most cases up to 8½*d.* per hour, and increases of 3*s.* 6*d.* per week, or 7*d.* per shift, to men and women 18 years of age and over, and of 1*s.* 9*d.* per week, or 3½*d.* per shift, to workers under 18 employed at gas undertakings generally in Great Britain. Other changes affecting large bodies of workpeople were increases in wages granted to men employed at blast furnaces, iron puddlers and millmen in the Midlands, pottery workers in North Staffordshire, and men and boys employed in the coach-building trade.

The number of trade disputes beginning in October was 79, and the total number of workpeople involved in all disputes in progress was 67,900, as compared with 205,000 in the previous month, and 80,400 in October, 1917. The estimated total aggregate duration of all industrial disputes during the month was 282,400 days, as compared with 831,300 days in September, 1918, and 503,200 days in October, 1917.

An outline has been issued of the measures which the Government propose to adopt to tide over the period of demobilisation and resettlement. The measures cover civilian war workers, the armed forces and the women employed in the munitions industry. Emphasis is laid upon the following point. It is not for a single moment intended that the resettlement of men and women in peace industries should be carried out solely by bureaucratic agencies. On the contrary, it is anxiously hoped and desired that every reputable voluntary agency in the country which can help will come forward and render assistance. In order to guard against waste of effort and labour, at a time when such waste is above all things to be avoided, it is necessary that as far as possible all workpeople should be placed by the Employment Exchanges so as to avoid such contingencies as two or three jobs being found for the same man by agencies working in isolation. The experience and local knowledge which voluntary agencies, however, such as the Labour Advisory Committees (composed half of employers and half of workpeople) possess will be invaluable, in guiding and directing fruitfully the machinery of the exchanges. In the early days of the war those who could not serve in the armed forces of the Crown set themselves to do all they could to stimulate recruiting and secure men for the Army and Navy. It is now asked that the same energy and enthusiasm should be devoted in the reverse direction, that is to say, to securing suitable appointments for the men who are returning after serving their country on the seas and in the field.

The department now responsible for dealing with questions as to the priority of release from the Colours of officers and men serving with H.M. Forces is the Demobilisation and Resettlement Department of the Ministry of Labour, 6, Whitehall Gardens, London, S.W. 1. Inquiries on the subject should be addressed to that department and not to the Admiralty, War Office, Air Ministry, Ministry of National Service, or Ministry of Reconstruction.

The Admiralty, War Office and Air Ministry will continue to deal with individual applications for the release of officers or men on compassionate grounds.

An employer who wishes to insure that a man now serving with the forces shall be earmarked for early release when general demobilisation begins should ascertain his full name, regimental number and rank, the full name of his unit, and the Expeditionary Force or Command where he is serving, and should then fill up and send to the local Employment Exchange a specially printed postcard (E.D. 406), copies of which may be obtained from Employment Exchanges.

It should be clearly understood that the general demobilisation of the forces has not begun. A limited number of pivotal men will be released in advance of general demobilisation. The number is small, and the industries entitled to receive a proportion are being notified of the procedure to be followed.

The Ministry of Labour make the following announcement:—

The scheme of out-of-work donation will come into operation on Monday next, the 25th inst., and out-of-work donation policies will not be issued before that date.

Donation will ordinarily be paid as follows: To ex-members of H.M. Forces, on Thursday, up to the preceding Tuesday inclusive; to civilian workers on Friday, up to the preceding Wednesday inclusive; and the first days for receipt of donation in the ordinary course will therefore be Thursday, December 5, or Friday, December 6. Subject to previous application however, payment of the donation due up till Friday November 29, inclusive, will be made on Saturday November 30. The amount to be drawn on the succeeding pay day will, of course, be correspondingly reduced. Ex-sailors, soldiers and airmen will be entitled to out-of-work donation policies, available for twelve months, if they have actually served with the forces during the present war, and civilian workers will be entitled to out-of-work donation policies, available for six months, if they are British subjects and became "employed contributors" under the National Health Insurance Scheme before August 25, 1918, and in the case of boys and girls, between 15 and 16, if they entered employment before that date. Unemployed persons desiring to claim donation should, on and after November 25, attend at an Employment Exchange or Branch Employment Office, taking with them their discharge or other military certificates if they served in H.M. Forces during the present war, or their health insurance record cards and health insurance contribution cards if civilian workers. In ordinary cases attendance daily or as otherwise directed between specified hours at the Employment Exchange or Branch Employment Office will be required as a condition of receipt of donation.

Rates of Donation:—Men over 18 years of age, 24*s.* a week; women over 18 years of age, 20*s.* a week. (With supplementary allowances for dependent children of 6*s.* a week for the first child under 15 years of age and 3*s.* a week for each additional child under that age.) Boys between 15 and 18, 12*s.* a week; girls between 15 and 18, 10*s.* a week. (Subject to attendance if required at a course of instruction under the Board of Education or other central authority.)

Donation does not become due until after the applicant has been unemployed and has attended at the Exchange for three consecutive working days, and payment will not be made for these three days.

Speaking last Tuesday at a meeting of the shareholders of the British Westinghouse Electric and Manufacturing Company, Limited, with a view to discuss a plan for the increase of the capital of the company by 5,000,000*l.*, the chairman, Mr. J. Annan Bryce, M.P., said that Germany will strain every nerve to meet by increased production the tremendous claim for reparation and indemnity which every consideration of justice demands should be imposed upon her. In one important respect, the speaker added, she has a great advantage over ourselves. Here enterprise has not been saddled during the war with the colossal

burdens in the form of income tax and excess profits tax which British enterprise has had to bear. The balance-sheet of a German competitor, the Allgemeine Electricität Gesellschaft, shows that at the end of 1915 they had cash resources of 7,000,000*l.* accumulated for dealing with work after the war, and it is reasonable to suppose that those resources may have been greatly increased during the three subsequent years. The Allgemeine and its associated companies have together a capital of 50,000,000*l.* In what form their available resources at present exist we do not know, but even supposing they are largely in the form of Government loans it is perfectly certain that the organising genius of the Germans will secure that they become available, by State credit or otherwise, for the vital needs of the country as a whole. Even a Socialist Government will see to that. Do not let us imagine, Mr. Bryce further stated, that the Germans won't have a market. Even if the loathing which their bestial methods have inspired prevents their direct access to the markets of the belligerent countries, it will require great ingenuity to prevent their indirect access even to belligerent countries. The neutral markets are open to them—Sweden, Norway, Denmark, Holland, Spain—and those in other parts of the world, countries in which the capitalist classes have, owing to the war, increased enormously in riches which they are eager to employ in every kind of industry for which these countries may offer a field.

Moreover, the neutral countries themselves where the capitalists have become rich will, and indeed do, wish to take a hand in the electrical industry for which some of them, notably Sweden, Norway and Spain, are admirably adapted by their command of water power

Then there is America. The years of the war before she entered it gave her gigantic profits, in which her subsequent expenditure, lavish though it has been, has not yet made any considerable hole. From being a debtor she is now a creditor country. She has already advanced to other belligerents, including ourselves, 1,600,000,000*l.* Her technical knowledge is of the best, the keenness and energy of her manufacturers immense, and the productive power of her workmen unsurpassed. Therefore, the British works are up against Germany fully equipped and desperate, the neutrals rich and eager, America able, rich and determined. In the United Kingdom, moreover, the Westinghouse Company has able and powerful competitors, some of whom, such as Dick, Kerr and Company, and the General Electric Company, have lately effected amalgamations, and secured large increases of capital, and the necessity imposed upon the Westinghouse Company to follow their example.

Speaking last week at the ordinary general meeting of the shareholders of Messrs. Dick, Kerr and Co., Ltd., the chairman, Mr. Claud T. Cayley, said that the works had continued to be fully employed. During the past few months the demand for certain purely war products having become less urgent, opportunity had been taken to establish a process of gradually changing over, and in this connection it was pleasing to note that the Ministries of Munitions and Reconstruction had given considerable assistance. While, therefore, there must inevitably be a hiatus of disorganisation, he hoped to be able to retain the continuous services of a considerable portion of the workpeople, first of all in the operations necessary to rearrange the factories, and later in standard production, provided raw material was available.

The question of the Demobilisation and Resettlement of the Army is dealt with in detail in a pamphlet now issued at the price of 2*d.* by the Ministry of Reconstruction. The greater part of the pamphlet is intended to be descriptive of the process as it affects the non-commissioned officer and private soldier, and the information is very clearly conveyed in the form of question and answer. Two former pamphlets issued by the same Ministry dealt with the Aims of Reconstruction and with Housing in England and Wales.

In the seventy-seventh quarterly balance sheet, to September 30 last, issued by the General Federation of Trade Unions, the secretary, Mr. W. A. Appleton, says that the days that lie ahead are full of dangerous possibilities for British industry. Already the air is thick with the sinister promises of ambitious politicians who, posing as the friends of labour, seek only in the labour movement a force for the advancement of their own mediocre ability. The problems of construction are greater even than the problems of destruction. The Management Committee of the General Federation believes that the aggregate commonsense of the people will solve those problems just as it overcame all the difficulties of the world war. Confidence, states the secretary, is the first essential to success, and after confidence a determination to deal only with fact and truth. Political power, he adds, has its uses, but it will not enable the trade unionist or anyone else to override economic law. The control of labour and industry which has obtained during the war cannot be immediately abolished, but its continuance for a moment beyond the absolutely necessary periods would justify, and would probably result in wholesale emigration to the freer United States of America.

The report further states that the membership shows an increase of 98,233, making a grand total of 1,158,864 members. The societies affiliated to the Federation have now a central reserve fund of 254,302*l.*, of which 120,000*l.* is invested in War Bonds.

Lord Pirrie, Controller-General of Merchant Shipbuilding, issued last week a manifesto to shipyard workers and marine engineers, in which he states that the British Mercantile Marine has been one of the most decisive factors in bringing the war to a successful conclusion, but even now there must be no slackening of effort in shipbuilding, as ships are as vitally necessary to-day as at any period in the history of this country. During the war Britain has lost 9,000,000 tons of shipping, whilst Allies and neutrals have lost 6,000,000 tons. The world's production during the war has been considerably less than normal, so that the world's shipping is now more than 15,000,000 tons below the tonnage which would have existed to-day had there been no war. Millions of troops are waiting to be transported to their homes. Thousands of cargoes of foodstuffs and raw materials, which have been held up during the last four years are waiting for transportation. The foodstuffs are urgently required not only in this country, but in every country in the world, where the great war has dislocated all the usual channels of supply. The raw materials are equally necessary for the reconstruction of British industries, and in order to provide work for the millions of workers who are waiting to return to their pre-war occupations. Under these circumstances Lord Pirrie appeals with confidence to the shipbuilding and marine engineering industries of the country not to relax their energies, and thereby to ensure that the greatest victory in the world's history shall be followed by an unequalled period of industrial activity and prosperity.

The Prime Minister in December, 1917, stated "Victory is now a question of tonnage, and tonnage is victory," and to this Lord Pirrie said he might add, "Peace is a question of tonnage, and tonnage is prosperity."

In moving in Parliament last Monday the second reading of the Wages (Temporary Regulation) Bill, Mr. G. Roberts, Minister of Labour, said the main purpose of the measure was that for a period of six months during which industries would be turning from war time production to peace production, the present level of wages should be maintained. Legislation was necessary, since the provisions of the Munitions of War Act would cease to be operative as the manufacture of munitions ceased, and as there was no immediate prospect of the cost of living being reduced, it was necessary to maintain wages at the level to which they had been raised, in order to meet that cost. The changes in wages which had taken place during the war covered, in regard to men, all the industries concerned whether they were or were not producing munitions, therefore no new obligation would be imposed by the Bill. In regard to women, the change of wages during the war had not covered the whole trade or industry as in the case of men, and it was of great importance that women should be protected in equal degree with men. The Bill, which was to operate for six months, only proposed that wages which had resulted from orders under the Munitions of War Act, or from awards or agreements, should be maintained. Where an order did not apply, power was being taken by the Ministry of Labour to make orders. The place of the Committee on Production would be taken by interim arbitration tribunals, consisting of employers' and workpeople's representatives with an independent chairman, and women would be represented where women's wages were concerned.

Control of Imported Goods: Italy.—According to *The Board of Trade Journal*, H.M. Ambassador at Rome reports that iron, steel and cast-iron goods have been removed from the list of goods which cannot be imported into Italy by private firms. This concession includes machines, machinery parts, tools and machine tools.

Personal.—Sir W. G. Armstrong, Whitworth and Co., Limited, of Openshaw, Manchester, have now appointed the following district representatives throughout the country, and have opened permanent district offices in connection with their tool steel and small tools business:—London and Southern District: Representative, Mr. Ernest Wilson, 8, Great George-street, Westminster, S.W. 1. Scotland and Ireland: Representative, Mr. A. S. Jones, 137A, St. Vincent-street, Glasgow. Midland District: Representative, Mr. Walter Todd, 158–161, Great Charles-street, Birmingham. North-Eastern District: Representative, Mr. J. D. Smith, Pilgrim House, Filgrim-street, Newcastle-on-Tyne. Lancashire and Wales: Representative, Mr. T. W. Etchells, 5, John Dalton-street, Manchester.

NOTES FROM THE NORTH.

Glasgow, Wednesday.

Scotch Steel Trade.—Already some of the changes, which were bound to take place when urgent war work came to a cessation, and the more peaceful requirements of normal times were once again the order of the day, have come into operation. This is especially noticeable in the steel trade, where much of the material forming the daily output, such as plates, sectional bars, joists, &c., is as necessary in peace time as in war. Steel of all kinds is greatly in requisition now for ordinary mercantile work, and manufacturers find themselves in the happy position of having such well-filled order books as shall keep them going during the difficult period of reconstruction. Then, the shipbuilders will continue to make extensive demands upon steelmakers for some considerable time to come; they are only too willing to take advantage of the permission to undertake private orders as soon as berths become vacant. That certain restrictions attach to this concession should be no deterrent to active business, for no one realises more keenly than do the shipbuilders the great need there is for merchant shipping.

Scotch Pig-Iron Trade.—Although the altered condition of affairs will make many changes in industry these will in no way affect the pig-iron trade, as the demand for all brands will increase rather than diminish, especially when the restrictions on export come to be removed. Meantime there continues to be a brisk demand for hematite, the steel works rapidly absorbing every available ton of output for the production of the constructional work, &c., required by the shipbuilding yards. There is still a certain shortage of foundry iron, particularly of No. 3.

Malleable Iron Trade.—In the malleable iron trade, as in other branches of industry, some very radical changes are inevitable in the scheme of readjustment, but, so far as can be seen, there is little risk of any period of dull trade. Both at home and abroad the ordinary mercantile consumer has suffered severely from want of material, so that, now that malleable iron makers are free to resume operations from the old standpoint, it will be possible to ensure adequate and speedy deliveries as required. An era of prosperity certainly looms ahead.

Iron and Steel Exchange for London.—We are informed that an iron and steel exchange has been founded in London by a group of some 40 of the leading British firms engaged in the iron, steel and metal industries. It comes into being at an auspicious moment, when the whole time of industrial activity is being turned from purposes of war to purposes of peace. The secretary's office is at 113, Queen Victoria-street, E.C. 4, and for the purposes of its business, the London Iron and Steel Exchange, Limited, has secured the great Pillar Hall of Cannon-street Hotel.

Plant and Machinery for Civil Work.—The Minister of Munitions announces that contractors in possession of plant and machinery owned by the Ministry of Munitions who wish to utilise such plant and machinery for civil work may do so provided they notify the superintendent engineer in their area within one week from the date upon which the plant and machinery was first used for purposes other than those for which it was provided. The utilisation of such plant and machinery will impose no obligation upon the contractor to purchase or the Ministry to sell, although should a sale not be effected to the contractor he will be required to pay a reasonable hire, which, unless an agreement exists to the contrary, will in no case exceed the rate of 20 per cent. per annum upon the cost price of the machine, and also to release the machine when required to do so by the Minister.

University of London.—Under the statutes of the university, facilities have been afforded to students of other universities, approved for the purpose, for proceeding to higher degrees in the University of London without taking a lower degree. Since 1901 about 350 students from British, Colonial, Indian and foreign universities who have obtained degrees in those universities, or who have passed the examinations for degrees (even though they have not received the degree) have been registered as "internal students" with a view to their proceeding to the degrees of Master and Doctor. A pamphlet now issued, containing revised regulations, is due to the desire of the university still further to encourage students from all parts of the Empire to continue their studies in London, where exceptional opportunities exist for research work in almost all subjects. Overseas students, on giving the necessary details with regard to their previous courses of study, the degrees which they have obtained, and the examinations which they have passed, may be informed before they leave their own country whether they can be registered as students for higher degrees, and, if so, under what conditions. They may further be advised as to the selection of a college, school or institution for the particular subject of research which they desire to pursue. The minimum period of residence in London for registered students proceeding to higher degrees under these regulations is two years, subject to their compliance with the other conditions laid down. The pamphlet contains not only the special regulations relating to the registration of persons as students for higher degrees, but also a conspectus of the requirements for higher degrees in the several Faculties. It is intended to publish at a later date a handbook for post-graduate students, describing the facilities for instruction in various Faculties and for study in libraries, laboratories and museums.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—But little work has been done in the large steel works during the past week, most of the men seizing the opportunity of the cessation of hostilities to take a well-earned holiday after their arduous labours of past months. The stoppage of munition making has relaxed large stocks of steel, copper and other metals badly needed in the ordinary trading activities of the country. The prospects of full employment during the coming winter are bright. Many of the men drafted into the armament works have already returned to their old occupations, and women are being discharged by the thousand. Employment will be found for practically all male help, though employers generally, intend that returned soldiers shall have the first claim on them, and the whole of these will be reinstated as demobilisation proceeds. Overseas trade prospects are good. The upheaval in Germany and Austria will, it is considered, eliminate these countries as serious competitors for some time to come, and with Belgium and France as prospective large buyers, there is a bright outlook for both this country and the United States. It is anticipated that shortly the control regulations will be substantially relaxed, though up to the present nothing has been done in this direction. Contracts for other than direct munitions have not been cancelled, and it is expected that for months to come army supplies will continue in strong demand.

South Yorkshire Coal Trade.—The stoppage during last week has greatly affected the output, and accentuated an already serious situation. Supplies of house coal are scarcer than ever, and merchants have had a great difficulty in securing even a limited allotment. At most of the collieries there is a great accumulation of wagons, and the preference given to dispatches to the metropolitan area is causing much heartburning among outside dealers. In some districts there is almost a famine in house coal. The demand for steams continues brisk and seems to have been hardly affected by the stoppage in the big munition works. Stocks are very low, and all classes of fuel are in brisk request. Prices continue at the maximum. Gas coal supplies are on a reduced scale, the demand from inland works where stocks have been seriously reduced, being very pressing. Colliery slacks are also keenly sought, but there is no tonnage on the open market. The demand for blast-furnace coke continues as strong as ever, values being at full rates. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

REFRACTORY MATERIALS.—The Minister of Munitions has ordered as follows: No person shall, on or after October 1, 1918, until further notice, offer to sell or purchase, or sell or purchase, or deliver or take delivery of any of the refractory materials specified in a schedule he has issued, at a price exceeding the price set opposite the same in the said schedule, except under and in accordance with a special permit issued under the authority of the Minister of Munitions. All applications under this Order shall be made to the Deputy Controller of Iron and Steel Production, Ministry of Munitions, 8, Northumberland-avenue, London, W.C. 2.

MERCHANT TONNAGE LOSSES AND SAILINGS.—The losses of British, Allied and Neutral merchant tonnage due to enemy action and marine risks during the month of October, 1918, compared with preceding periods are set out below:—

Gross Tonnage.

Period.	British.		Allied & Neutral.		Total.	
	Month.	Quarter.	Month.	Quarter.	Month.	Quarter.
1917.						
Sept.	209,212	952,088	159,949	541,535	369,161	1,494,473
Oct.	289,973		197,364		487,337	
Nov.	196,560		136,883		333,443	
Dec.	296,356	782,889	155,707	489,954	452,063	1,272,843
1918.						
Jan.	218,621		140,842*		359,463*	
Feb.	254,303		130,629*		384,932*	
Mar.	224,744*	697,668*	174,197*	445,668*	398,941*	1,143,336*
Apr.	233,426*		83,684*		317,110*	
May	231,787		134,756*		366,543*	
June	165,849*	630,862*	112,705*	331,145*	278,354*	962,007*
July	162,524		142,314*		324,838*	
Aug.	176,854*		164,475*		341,329*	
Sept.	152,652*	512,030*	96,694*	403,483*	249,346*	915,513*
Oct.	83,952		93,582		177,534	

* Adjusted.

The tonnage of steamships of 500 gross tons and over entering and clearing United Kingdom ports from and to ports overseas was as under:—

Period. 1918.	Gross Tons.
April	7,040,309
May	7,777,843
June	7,430,388
July	7,713,808
August	8,156,639
September	7,815,061
October	7,594,476

This statement embraces all United Kingdom seaborne traffic other than coastwise and cross-Channel.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—There is some feeling of uncertainty as to prices and as to control of trade, but the prevailing opinion seems to be that for a while quotations will not be altered, and that there will be no immediate relaxation of conditions of trading. Home demand for Cleveland pig-iron is still heavy and needs of the Allies are very considerable, so much so that little or no iron is available for neutrals on behalf of whom there is very substantial inquiry. Applications for licences for exports to neutrals meet with little or no success. Stoppage of blast furnaces for the armistice holidays has been attended with difficulties on resumption of operations, the result being that output of foundry iron, which was already below the normal, has been reduced, and make of the lower qualities increased. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge are all quoted 95*s.*, and No. 1 is 99*s.*; whilst for shipment to France and Italy, No. 3 and the lower qualities are 122*s.* 9*d.* and No. 1 is 127*s.* 9*d.*

Hematite Iron.—In the East Coast hematite trade parcels for Allies are stated to be on a rather smaller scale. Home demand shows little change and is adequately dealt with. Mixed Nos. are 122*s.* 6*d.* for home use, and 147*s.* 6*d.* for export to France and Italy.

Foreign Ore.—Consumers of foreign ore are understood to have ample stocks, and good supplies are coming forward regularly against running contracts, but new business is quiet.

Manufactured Iron and Steel.—In the finished iron and steel industries slackness is noticeable in some branches, due to cancellation of Government orders, but demand for shipbuilding and constructional material is unabated. Such slackness, however, is not likely to be of lengthy duration as there are very numerous private orders to commence upon so soon as conditions permit. Meanwhile prices, all round, are unaltered. Principal market quotations stand:—Common iron bars, 14*l.* 15*s.*; best bars, 15*l.* 15*s.*; best best bars, 16*l.* 15*s.*; best best best bars, 17*l.* 15*s.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; iron ship rivets, 21*l.*; steel ship plates, 11*l.* 10*s.*; steel ship angles, 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel strip, 17*l.* 10*s.*; steel hoops, 18*l.*; and heavy sections of steel rails, 10*l.* 17*s.* 6*d.*—all f.o.t. at works. Export prices are not fixed, but they are approximately 40*s.* above home quotations.

Steelworkers' Dispute.—A dispute over steel sample passers' wages has assumed a serious aspect. Large Middlesbrough works are laid idle, and all members of the Steel Smelters' Society have been advised to cease work. The trouble has arisen in consequence of the decision of the Committee on Production not to uphold the sample passers' claims. The sample passers act as foremen in the smelting departments and their earnings range from 10*l.* to 16*l.* per week according to conditions of work in the different plants. During the war their increases varied from 2*l.* 10*s.* to 4*l.* 10*s.* per week, and in some cases even more. A proposal by the employers again to submit the points in dispute to arbitration on condition that the men resumed work has been declined by the sample passers, with the result that the smelters have struck work.

Coke.—Coke is more plentiful. Heavy local demand is quite adequately met. Medium blast-furnace kind is 33*s.* at the ovens, and low phosphorus quality 35*s.* 6*d.* at the ovens.

ENEMY AIRCRAFT EXHIBITION.—The exhibition of enemy aircraft in London at the Agricultural Hall, is of special interest to the expert, but it none the less contains very much that appeals strongly to the general public, and the public will gain by visiting it. The sight of the bombing machines, Gotha, A.E.G. and Friedrichshafen, brings home the war and our victory to the public perhaps more vividly than do the German cannon in the Mall. It would indeed be instructive if a Handley-Page could be placed beside the Gotha. Most interesting are the small models hung on the wall, showing the comparative size of a Gotha, a German Giant aeroplane, and the British Camel which brought the giant down. Likewise also the wing of a Camel hung against the wing of a Gotha. The British Camel is a curious little machine with its straight upper wings, while the lower planes are inclined upwards (dihedral angle); it is a fast machine, and great is the havoc it has wrought among the Huns. The armoured trench-strafer takes the thoughts back to the infantry. When an aeroplane flew low over the trenches it came under intense fire from rifles and machine guns, and the airmen ran heavy risks of being hit or of having their petrol tank punctured. The Germans sometimes guarded against that by giving their trench-strafers armour. Nevertheless this particular machine, like many others of its kind, was brought down. The other side of the picture also comes to the mind: the heroism of the British airmen who every day flew low, without armour, to attack the German infantry and help the British assault. One bullet through a vital part of the engine—an ordinary mischance in flying—and the machine must crash, whatever the skill of the pilot. That is the special peril of low flying; it makes gliding impossible. If the pilot were shot, his observer's fate was sealed. The work of the Independent Air Force is represented by one De Havilland 9, a veteran of many daylight bombing raids on Germany. All honour to this war-worn veteran, which none the less looks "spick and span" among the dingy, battered German machines around it.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—The markets reopened this week under strong pressure. Over the week-end the tonnage had increased, and in view of the recent depletions in the stocks of coal and in the output of the collieries there is a general shortage, and shipments are being retarded. The complaint is now general that the shipments difficulties at the port of Cardiff are accentuated by the relative inefficiency of coal shipping facilities. Many of the tips are in a bad state of repairs and the view is held that unless measures are taken without delay to bring them up to date the lack in the supply of ample provision for the shipment of coal will react very prejudicially on the export trade in the immediate future. Exporters are regarding the outlook in this matter with growing apprehension. The pressure of the Admiralty demand shows no sign of relaxation, and the quantities available for export to neutral destinations remain limited to the figures determined upon some time ago by the Coal Controller and the Coal Exports Department of the Board of Trade. The market for other large qualities is also active, and smalls are being disposed of with little difficulty. The position in regard to pitwood is easy, and the supply is sufficient to meet the needs of the collieries.

Newport.—The conditions in the market for Monmouthshire coals remain unchanged. Shipments are not so heavy as they might be owing to the restricted outputs of the collieries following the armistice celebrations, through the week practically all the pits are working. Black Veins are the strongest feature, but the demand is also active for other classes of Western Valley as well as for the more bituminous Eastern Valley coals. Very little is being released for neutral destinations, the demand from allied countries being urgent and in excess of the available supplies. A better outlet is also being provided for small coals, for which an increased demand has taken place.

Irregular Colliery Stoppages.—Complaints have repeatedly been made by the coalowners of sudden stoppages at the collieries without the men giving the requisite 14 days' notice as provided in the general wage-rate agreement. In a number of cases it was decided to take proceedings to recover from the men concerned. Fortunately, the employers have acted very tactfully, and it was intimated at the Standing Joint Disputes Committee of the Welsh Coal Board yesterday, the summonses issued would be withdrawn in a number of cases, as the men concerned had given an undertaking that there would be no recurrence of these dislocating stoppages for a definite period. This intimation has resulted in other workmen following suit, and there now appears every prospect that this evil, which has been so much in evidence on the South Wales coalfield, may at least be appreciably diminished, if not eliminated.

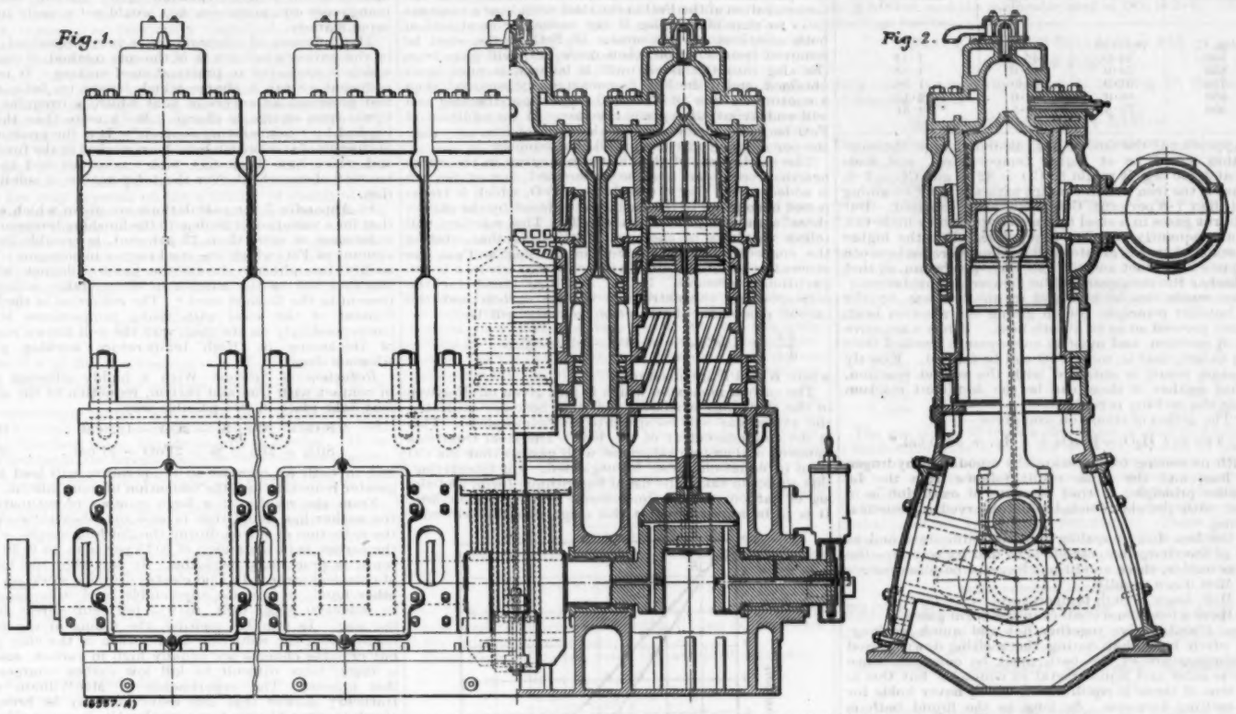
Clerks as Members of Miners' Federation.—Exception has been taken by the coalowners to clerks joining the Miners' Federation. It is pointed out that these men have access to confidential information and colliery companies are likely to be prejudiced if they become members of the federation. It is the aim of the latter, however, to secure as members all who are employed in connection with collieries whatever may be the class of work which they perform, and at the last meeting of the Coal Conciliation Board, the owners intimated very pointedly that if the federation persist in recruiting these men as members then the owners will have to take steps to protect themselves.

Demobilisation of Miners.—As far as South Wales is concerned only a very few miners have been released from His Majesty's forces. Arrangements are being rapidly completed with a view to the re-employment of the released men, but at a meeting of the Executive Committee of the South Wales Miners' Federation held here to-day complaints were made that in some instances the owners had not taken the necessary steps to provide employment for these workmen. It was, therefore, decided to request that a special meeting of the Joint Coal Board be immediately convened to deal with the whole question, and this will probably be done within the next few days.

THE ENGINEERING SOCIETY, KING'S COLLEGE.—We are asked to announce that the dinner of this society will be held at the Trocadero Restaurant on Friday, December 6, at 6.30 p.m. Service dress (slacks) or evening dress. All past members are invited. Application for tickets, price 10*s.* 6*d.*, should be made to Messrs. Bryce or Jotikasthira, King's College, Strand, W.C. 2.

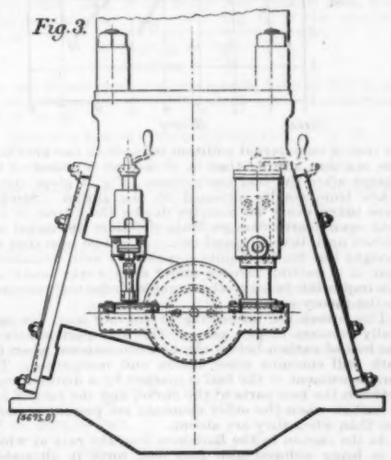
PRIVATE BILLS IN PARLIAMENT.—The Chairman of Committees in the House of Lords intimates that he will give favourable consideration to the introduction, during the next session of Parliament, of late Private Bills (*i.e.*, Bills not deposited in December in accordance with Standing Orders) for which urgency can be claimed owing to the armistice and prospect of peace. The Bills referred to are Bills which have been held up owing to the war and Bills dealing with new projects calculated to promote the work of reconstruction. Application for leave to introduce any such late Bills should be made early in the session in order to secure due time for their consideration. Before making this intimation the Lord Chairman has been in consultation with the Chairman of Ways and Means, who anticipates that a similar relaxation of Standing Orders will be allowed in the House of Commons.

THE WEISS HIGH-COMPRESSION HEAVY OIL ENGINE.



Elevation and Cross Section of Weiss Engine, Showing Conical Piston and Cylinder Liner. Together With Method of Supporting Main Bearings from Side

From our contemporary, *International Marine Engineering*, we reproduce on this page illustrations of a modified type of high compression oil engine which has been introduced by the Weiss Engine Company of 17, Battery-place, New York. The engine, which is rated at 400 h.p., has four cylinders 16½ in. in diameter, the stroke being 33 in. The engine operates on the two-cycle-system, and its special characteristic lies in the provision made for the effective scavenging of the spent charge. As shown in Figs. 1 and 2, there are two circular ports in the cylinder wall. The upper of these is an exhaust port, whilst the second is connected-up with a supply of air under slight pressure provided by a blower. As the piston uncovers the upper port the spent gases escape and, in view of the consequent rapid expansion and accompanying fall of temperature, the pressure within the cylinder is stated to drop slightly below the atmospheric. At this stage the piston uncovers the lower port and a supply of pure air from the blower sweeps into the cylinder. A further downward motion of the piston allows of the entry into the cylinder of air which has been compressed into the crank chamber to about 5 lb. per square inch. This air obtains access to the upper side of the piston by passing up between the spiral ribs which, as indicated in Fig. 1, guide the piston during the latter portion of its stroke. The volume of air sent into the cylinder is, it will be seen, considerably in excess of the piston displacement and the scavenging is in consequence very complete. The piston requires no baffle plate but has, as shown, a simple conical head which is not liable to distortion when heated. The fuel supply is sprayed into the cylinder under pressure, being fed to each cylinder in proper sequence by a distributing valve mounted at one end of the engine as indicated in Fig. 3. The other valve there shown is an air-distributing valve used in starting the engine. Both are driven from the crankshaft by spiral gearing. Piping (not shown in the illustrations) connect these distributing valves with the cylinders. The air is supplied by an independent compressor at 200 lb. gauge pressure. It is used, moreover, to spray the fuel into the cylinder, an adjustable reducing valve being utilised to this end, as the pressure necessary for effective spraying varies with the character of the oil used. The sprayer is fitted centrally into the cylinder head as shown in Figs. 1 and 2, whilst the starting air is admitted when required through the valve shown to the right in Fig. 2. Since the engine is intended for marine purposes, provision is made for reversing it by changing



End Elevation, Showing Oil Distributor Valve

over the distributing valves. This is effected by the hand levers represented in Fig. 3.

The ignition is automatic and the maximum pressure attained is about 500 lb. per square inch. The weight of the engine is said to be about 150 lb. per brake horse-power. Forced lubrication is fitted throughout.

Spitzbergen and Its Resources.—In an article in a former issue (Engineering, vol. civ, page 596) we gave particulars, illustrated by a map, of the mineral resources of Spitzbergen and of the British, Norwegian, Swedish, Russian and German claims to these. An expedition was recently fitted out and despatched to the islands with the full support of H.M. Foreign Office, who granted the protection of the British Flag. The expedition had in view and accomplished the following objects: To protect and further extend the claims of the Northern Exploration Company, Limited; to form a permanent camp upon the company's coal and iron properties; to take possession of the German claims; to investigate the rumours of claim jumping and to put a stop to any infringement of the company's rights; and to make preparations on a considerable scale for the getting of coal and iron in the spring of 1919.

BALANCED REACTIONS IN STEEL MANUFACTURE.*

By Andrew McCance, D.Sc., A.R.S.M.

There is no satisfactory theory of the reactions which take place in the open-hearth furnace during the manufacture of steel. A general view presents several separate groups of facts with independent explanations which have not yet been connected, one with the other, in logical sequence. In this paper a rough outline is put forward of these facts considered from the standpoint of physical chemistry and of well-established theoretical principles, and the connection which exists between the final quality of the solid steel and the antecedent conditions during manufacture is traced with special reference to the contained gases. Though the author deals mainly with the open-hearth process, much of course is applicable to the other processes of steel manufacture where the general conditions are similar in principle though different in detail.

Melting.—During the melting period in the furnace the metal is in contact with a variety of gases, such as CO_2, water vapour, nitrogen, as well as unburnt oxygen and CO, with which it can react under appropriate conditions. There is one fact which guides us, however, in determining the dominant reaction from among the many complex reactions possible, and that is, that as the average temperature of melting gets lower there is greater oxidation of the scrap and consequently more FeO in the slag. Every steel-smelter knows that with a cold heat there is a more open slag and a greater tendency to go on the boil without ore than when the charge is melted hot. In terms of slag analyses, the following are two typical cases:—

	FeO.	SiO_2.
Cold heat	36·3	36·4
Hot heat	20·8	45·0

The higher the temperature is, the rate of oxidation of the iron gets less, and possible reactions may be considered in the light of this fact.

1. The direct oxidation of the iron by the air is ruled out of account at once, since it is known that the rate at which scale forms on an iron surface increases greatly with temperature. Direct oxidation does, of course, take place, but it is not the main cause of oxide formation, but only a secondary one.

2. Oxidation by CO_2 is possible in two ways—

$$Fe + CO_2 = FeO + CO - 2{\cdot}3 \text{ cal}\dagger \quad . \quad (1)$$

$$3\,Fe + 4\,CO_2 = Fe_3O_4 + 4\,CO - 1{\cdot}4 \text{ cal} \quad . \quad (2)$$

These are balanced reactions, of which the first has been worked out fairly fully, and the composition of the gases

* A contribution to a general discussion on "The Occlusion of Gases by Metals," at the Faraday Society, on Tuesday, November 12, 1918.

† Baur and Glässner, *Zeit. physik. Chem.*, 1903, vol. lxiii, page 354.

which are in equilibrium with iron and ferrous oxide at different temperatures is as follows :—

Temperature.	CO.	CO_2.	Ratio $\frac{CO}{CO_2}$
deg. C.	per cent.		
550	54·0	46·0	1·16
650	58·0	42·0	1·38
750	61·0	39·0	1·56
850	68·0	32·0	2·12
900	71·5	28·5	2·51

In Appendix II the author has calculated what the composition would be at higher temperatures, and finds that at 1,500 deg. it would be CO = 92·4, and CO_2 = 7·6, so that if the iron was in contact with any gas containing more than 7·6 per cent. CO_2 it would be oxidised. But the burnt gases in a steel furnace contain very little CO, and consequently reaction is possible. But the higher the temperature the greater will be the difference between the gases in contact and the gases in equilibrium, so that the higher the temperature the greater the oxidation.

This result can be obtained in another way by the Le Chatelier principle, for on giving the reaction heat, it must proceed so as to absorb heat. It has a negative heat of reaction, and must in consequence proceed from right to left, that is, more FeO will be formed. Exactly the same result is obtained with the second reaction, so that neither of these can be the dominant reaction during the melting period.

3. The action of steam on iron gives—

$$3\,Fe + 4\,H_2O = Fe_3O_4 + 4\,H_2 \ldots + 38{\cdot}5\ cal.*$$

With increasing temperature the amount of hydrogen gets less, and the same result follows from the Le Chatelier principle, so that the rate of oxidation is in accord with the slag condition as observed in practical working.

If the loss due to scaling is to be minimised and as little of the charge as possible is to find its way into the slag as oxides, three conditions have to be observed :—

1. Melt down rapidly.
2. Melt down at high temperature.
3. Have a low steam content in the burnt gases.

Nos. 1 and 2 give together hot and quick working. It is often held that during the melting-down period the temperature of the bath must be constant, since there is solid and liquid metal in contact ; but this is only true if there is equilibrium, which never holds for steel-melting furnaces. So long as the liquid bath is growing at the expense of the solid scrap there is a difference in temperature between them, and the quicker the rate of melting the greater must this difference be. Pyrometer observation shows, in fact, that the temperature of the liquid bath is rising steadily during the melting period.

The presence of steam in the burnt gases arises from the combustion of the hydrogen in the producer gas together with any undecomposed steam which has passed through the producer. The composition of the gas has therefore a direct bearing on the working of the furnace and on the loss of metal due to scaling.

As a result of this reaction the steel has an opportunity of absorbing hydrogen. There is no experimental evidence as to the extent of the solubility of hydrogen in iron in the liquid or solid state. Baraduc-Muller† found that the rate of evolution of hydrogen during solidification was not much greater than the rate of evolution after the steel had become completely solid. If there is little difference in the solubility in the liquid and in the solid state, it is unlikely that hydrogen is ever the cause of blowhole formation in steel.

Boiling Period.—After melting, the liquid bath has a covering of slag containing FeO and other oxides (which, however, take no part in the subsequent reactions), together with silica. Independently of how these constituents are combined one with the other, the slag can be regarded as an impure solution of ferrous oxide in silica. The addition of iron ore increases the strength of this FeO solution, and since there is no contrary evidence it must be inferred that iron oxide so added cannot act on the steel bath without first going into solution in the slag. The first action of the slag is to oxidise any Si and Mn in solution in the liquid metal ; but these reactions need not be considered here, since they do not give rise to gaseous reaction products. After they have been removed, however, the carbon is attacked according to the equation :

$$FeO + C = CO + Fe \quad . \quad . \quad . \quad (3)$$

The FeO is derived from the slag, but there are many reasons for believing that the reaction is by no means confined to the surface layers of metal, but takes place equally throughout the whole mass of liquid. If the slag is scraped off during the boiling period, the metal still goes on boiling vigorously, and can do so for a considerable time although there are only traces of slag in contact with the steel. Clean pieces of Swedish charcoal iron containing 0·16 per cent. carbon lose all their carbon when melted in a magnesia crucible in an electric vacuum furnace.‡ When a local area in the bottom of an open-hearth furnace gets bad, the boil takes place much more vigorously over that area than elsewhere, and the slag may be projected some distance above the general level through the energetic action. Such facts point to the CO being liberated simultaneously throughout the mass of metal, and since the carbon is in solution, it entails that the FeO must also be in solution in the steel.

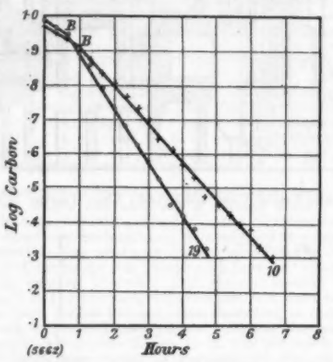
On this assumption the FeO is divided between two solvents, the slag and the steel, and the application of the partition law to such a system indicates that the concentration of the FeO in the steel must bear a constant ratio to that of the slag if the molecular condition of both solutions be the same. If FeO in the steel be removed from solution, then more FeO will pass from the slag into the steel, until a balance is once more obtained, and if the FeO be continuously removed, then a continuous flow of FeO will come from the slag and will endeavour to replace the loss. If no addition of FeO be made to the slag (in the form of iron ore) then the percentage content will fall continuously.

The mechanism of the carbon reduction in the open-hearth process can now be understood, for as the ore is added to the slag it dissolves as FeO, which is transferred in solution to the bath, and reduced by the carbon there with the production of CO. The reaction will follow the laws of chemical kinetics, so that, stating the concentration of the FeO in the slag as C_{FeO}, the concentration in the steel will be aC_{FeO}, where a is the partition coefficient. If C_C and C_{CO} stand for the corresponding concentrations of the carbon and the carbon monoxide, the reaction velocity will be :

$$\frac{dx}{dt} = K(aC_{FeO} - x)\,(C_C - x) - k(C_{CO} - x),$$

where K and k are constants.

The carbon monoxide which is first given off dissolves in the steel, but whenever the steel becomes saturated the excess gas will escape into the atmosphere. This is the commencement of the boil. The steel from this moment is therefore saturated with gas, so that the CO term in equation 2 can be neglected. On integrating, this equation takes the usual logarithmic form, and the log of carbon against time should plot a straight line. It is to be remembered at this stage that this will only



be true if no external addition is made to the FeO after the reaction starts—that is, if no ore is added to the charge after the boil commences. Fig. 1 gives curves taken from results obtained by the author. Samples were taken every 20 minutes during the course of two acid open-hearth charges from the time the metal was melted until it was tapped out. It will be seen that the straight line fits the points surprisingly well, considering that in a melting furnace under steel works conditions it is impossible to keep other complex influences constant, as the theory assumes.

The curves are interesting in another way, for each really consists of two parts. The first part relates to the loss of carbon before the boil commences, when the bath still contains some silicon and manganese. The commencement of the boil is marked by a distinct angle between the two parts of the curve, and the rate of loss of carbon when the other elements are present is much less than when they are absent.

As the carbon in the bath gets less, the rate at which it is being reduced also gets less, until it ultimately becomes of the same order of magnitude as the rate of the reverse reaction brought about by the presence of the CO. When it becomes equal to the latter, then equilibrium is established and no further carbon is oxidised. When this takes place, equation 2 reduces itself to :

$$\text{Constant } \frac{K}{k} = \frac{C_{CO}}{a\,.\,C_{.\,FeO}\,.\,C_{.\,C}} \quad . \quad . \quad (4)$$

How far the attainment of equilibrium is possible in a melting-furnace is a difficult question to decide. The carbon, for one thing, is never constant, but is always dropping slowly, and the time element in practical working necessitates the adoption of other means for controlling the oxides in solution. But the conditions, however they may vary, are always trying to approach equilibrium, and alterations in the external conditions will have the same effect whether it is attained or not.

Since the steel is saturated, the upper term will remain constant in equation 4, and so the lower the carbon in the steel at the final stage, other things being equal, the higher the amount of FeO and *vice versa*, which accounts for the fact that mild steels are more difficult to deoxidise than higher carbon steels made under the same conditions.

Supposing lime is added to a slag which is in equilibrium with the metal underneath, then the FeO concentration of the slag is reduced and the metal is no longer in equilibrium, but contains excess FeO which will act on the carbon available until equilibrium is once more attained. For this reason CaO can replace ore with advantage towards the end of the boil, but it is obvious that this action cannot take place at the beginning of the boil, since the effect would then be directly opposite and it would retard oxidation. Any diluent, such as manganese ore, magnesia, &c., would act exactly in the same manner.

The influence of temperature is very important, and in the author's opinion it is the one method of control which is neglected in practical steel-making. It is not sufficient to tap a charge which leaves no ladle skull and possesses an excess of heat which is irregular and varies from charge to charge. Much more than that is implied by "temperature control." It is the production of charges of steel which have been worked in the furnace, and which have been cast with a constant and known amount of superheat over the temperature of solidification.

In Appendix I the calculations are given which show that for a variation of 50 deg. in the finishing temperature a decrease of more than 33 per cent. is possible in the amount of FeO which the steel carries in solution. The author has already shown the great influence which this fact has on the number of non-metallic inclusions present in the finished steel.* The reduction in the FeO content of the steel with rising temperature reacts correspondingly on the slag, with the well-known results of thickening it. High temperature working gives siliceous slags.

Reduction of Silicon.—With a highly siliceous slag in contact with iron and carbon, reduction of the silica may take place in two possible ways :

$$SiO_2 + 2C = Si + 2CO - 122\ cal \quad . \quad . \quad (5)$$

$$SiO_2 + 2Fe = Si + 2FeO - 51\ cal \quad . \quad . \quad (6)$$

and in both an increase in temperature will lead to a greater reduction and the formation of more silicon.

From the results of a large number of estimations the author has found that in acid open-hearth working the reduction of silicon during the finishing stages, when the carbon is in the region of 0·15 per cent. to 0·20 per cent., is practically negligible. It is within the limits of chemical error. In acid electric-furnace work, on the other hand, it is quite appreciable, and it is possible to reduce 0·2 per cent. to 0·3 per cent. direct from the slag. In crucible melting, the killing of the melt results from the reduction of the silica of the clay pot, but crucible charges are usually high in carbon, and it is much more difficult to kill low carbon charges in this manner. The experiments of MacWilliam and Hatfield† showed that this reduction may be brought about in open-hearth furnaces, but it is noticeable in their figures that when reduction takes place the carbon is about 0·40 per cent.

It is fairly evident, therefore, that it is the carbon which reduces the silica and not the iron. The reverse reaction in equation (5) is important when additions of silicon are made later for deoxidation purposes.

Manganese behaves similarly, and need not be considered separately.

Carbon Monoxide.—The presence of CO in solution in iron entails a further reaction with the FeO :

$$FeO + CO = CO_2 + Fe \quad . \quad . \quad . \quad (7)$$

—a reaction which has been studied over a considerable range by Baur and Glässner‡ for solid Fe and FeO. Their results, however, will not enable us to arrive at quantitative conclusions regarding the equilibrium of the same materials when they are in a state of solution. Qualitative deductions in accordance with experimental facts can, however, be made. This equilibrium is independent of pressure, and the ratio of $\frac{CO}{CO_2}$ under reduced pressure is therefore constant. This is shown by the results of Barraduc-Muller§ in the composition of gas drawn off an ingot in four periods between the time of casting and the solidification of the metal :

No.	CO.	CO_2.	Ratio $\frac{CO}{CO_2}$
1	43·2	5·2	8·3
2	56·8	4·0	14·2
3	40·8	4·8	8·5
4	24·8	2·8	8·8

Excepting No. 2, the constancy is extremely good when the difficulties of the experiment are remembered.

A lowering of the temperature of working greatly decreases the ratio (see Appendix II). Thus in cast iron‖ :

Cast Temperature.	Ratio $\frac{CO}{CO_2}$
1,428	30·2
1,348	13·7
1,264	7·2

The bearing which this has will be considered in the next section.

The Formation of Blowholes.—It is a general law that the solubility of gases in liquids increases as the temperature is lowered, but at the freezing-point the solubility is much less in the solid state than in the liquid condition.

* Deville, *Liebig Ann.*, 156, page 76. ; Prouner, *Zeit. physik. Chem.*, 1904, page 385.

† Journal of the Iron and Steel Institute, Carnegie Res. Mems., 1914, page 216.

‡ Yensen, Bulletin, Illinois University, No. 72, page 41.

* Journal of the Iron and Steel Institute, 1918, 1, page 289.

† *Ibid.*, 1902, 1, page 54.

‡ *Zeit. physik. Chem.*, 1903, vol. xliii, page 461.

§ Journal of the Iron and Steel Institute, C.S.M., 1914, page 216.

‖ Journal of the Iron and Steel Institute, C.S.M., 1916, page 66.

As a result, all gases will show strongly the effects of primary segregation—that is, the concentration of the solution in the last portions to solidify. If during the progress of this concentration the limit of solubility is reached, then the excess gas will escape and blowholes will be formed. At the finishing stages in the open-hearth furnace, as previously explained, the steel is saturated with CO and the amount of gas will depend only on the temperature. If this is constant, then all steels will start with the same amount of gas in solution. Starting, then, with a quantity of liquid steel containing CO and CO_2, and neglecting for the moment all other reactions except (7), cooling will result in more CO_2 being formed at the expense of the CO. But the steel in the solid state may have a very limited solubility for CO_2, and if this be exceeded, blowholes will be formed at the instant of solidification. The formation of blowholes not only depends on the quantity of dissolved gas but also on the variety of gas. No attention has hitherto been paid to this possibility, and to explain all the peculiarities in the relations between these gases and steel it is only necessary to assume that steel in the solid state has a much greater solubility for CO than for CO_2.

When equilibrium is established according to equation (7):

$$K = \frac{C_{CO_2}}{C_{FeO} \cdot C_{CO}},$$

where C x is the concentration of X. When there is much ferrous oxide in solution, the ratio $\frac{CO_2}{CO}$ will be correspondingly great, and when the steel solidifies, if the amount of CO_2 is greater than the metal can hold in the dissolved state, blowholes will be formed. If, on the other hand, the ferrous oxide be removed, the amount of CO_2 will shrink until the ratio $\frac{CO_2}{CO}$ corresponds to give the correct value of K, and on solidification the saturation limit may never be attained. It is important to notice that the total volume of gas (expressed as c.c. per gramme of metal) may remain quite unaltered by the reduction of the FeO, so long as direct reduction of the gases does not take place. How well this accords with the experimentally determined volumes of gas by different observers will be seen by the following results. Boylston,* using all the well-known deoxidisers, found:

	c.c. per 100 Grammes.
Average for deoxidised metal	126
Average for oxidised metal	125

Goerens,† using quite a different method for the estimation of the gas, gives the mean of two charges in a basic open-hearth furnace, the samples being taken from the bath before and after deoxidation:

	c.c. per 100 Grammes.
Average before deoxidation	67
Average after deoxidation	88

Baker,‡ from two similarly-melted charges of crucible steel:

	c.c. per 100 Grammes.
Steel without blowholes	132
Steel with blowholes	67

With regard to the latter, the two charges were melted in separate pots at the same time, and it is admittedly difficult to determine similarity of condition during melting so far as gas content is concerned.

It may, however, be taken as proved that deoxidation does not necessarily mean the diminution of the total gas in solution.

Since deoxidised steel contains less FeO, the gas given off should have a higher $\frac{CO_2}{CO}$ ratio than oxidised steel, and the results of Goerens again enable this to be confirmed. Taking samples from two electric furnace charges after the removal of the phosphorus slag and again after deoxidation with ferro-silicon and ferro-manganese, and extracting the gas, it was found:

	$\frac{CO_2}{CO}$ Ratio per cent.	
	1	2
Before deoxidation ...	8·8	7·3
After deoxidation ...	60·0	21·3

In the first charge the manganese was 0·08 per cent. and in the second 0·13 per cent. at the time of taking the first sample, showing that the former was in a more highly oxidised state than the latter, and consequently it gives a greater difference after deoxidation. The theoretical deductions are strikingly confirmed.

As calculated in Appendix II, the composition of the gas in equilibrium with solid iron and FeO at the solidifying temperature, taken as 1,500 deg. C., is roughly CO_2 = 7·8 per cent., CO = 92·4 per cent., so that even if pure CO_2 were given off from the solidifying steel it would immediately be reduced again to CO by reaction with the solid iron until the composition of the gas approached this value. The fact that the gas liberated from an ingot burns with the blue flame of CO does not imply that it was given off as such during the solidification.

Estimation of Gases in Steel.—In steel, from what has previously been said, the gas content in the solid state will be proportional to the gas content in the liquid solution, but the determination of the exact composition and quantity of this gas presents grave practical difficulties.

Two methods only so far have been used—the extraction of the gas by heating the sample in a vacuum (Baker, Boylston, Donaldson, &c.) and the fusing of the sample in a vacuum with tin and antimony, which have practically no dissolved gas themselves (Goerens). In the first method, any gas which is evolved, which does not possess the composition necessary for equilibrium according to equation (7) for the temperature of the experiment, will tend to react with the steel until it does possess that composition. Thus the composition found must have been modified in a quite indeterminate manner by reaction taking place at a lower temperature. The sum of the volumes of CO_2 and CO, however, gives the exact volume of the mixed gases at the temperature of solidification. The composition may not be the same.

With regard to the second method, the carbon contained in the steel is insoluble in the alloy and floats to the surface, where it remains, at the same time reducing the CO_2 in accordance with the reaction:

$$CO_2 + C = 2\,CO$$

This reaction not only varies with the temperature, but also with the pressure of the gases, so that the results obtained only give the volume of the gas originally contained exactly, when expressed as CO_2 equivalent. That is, the volume of CO_2 plus $\frac{1}{2}$(volume of CO) gives exactly the volume of mixed gases originally contained by the steel.

How far the composition is altered depends on the rate of evolution, so that the effect is merely to mask the differences in composition by an uncertain amount. Qualitative deductions can, however, still be drawn from the results, and it is the object of this paper to show how such deductions give an insight into the complex conditions existing in liquid steel during manufacture.

APPENDIX I.

The heat of reaction at ordinary temperatures for the reaction:

$$FeO + C = CO + Fe - 35{\cdot}6 \text{ cal.}$$

is − 35·6 cal, and the heat of reaction at the temperature of a melting furnace, 1,600 deg. C., can be calculated in the following manner:—

From Nernst theorem, using the accepted symbols:

$$Q = Q_o + \beta T^2$$

$$\frac{d\,Q}{d\,T} = 2\beta T = C_v - C_p.$$

There are no measurements of the molecular heat of ferrous oxide, since it has never been isolated pure, but Richards gives the value at 0 deg. C. of the specific heat of:

Fe_2O_3 as 0·1456
Fe_3O_4 as 0·1447

so it can be assumed that the specific heat of FeO is in the neighbourhood of 0·145, which gives a molecular heat of 10·45.

Molecular heat of carbon at 0 deg. C....	1·92
Molecular heat of CO at 0 deg. C. ...	6·71
Molecular heat of Fe at 0 deg. C. ...	6·15

(These values are calculated from Kaye and Laby, "Physical Constants.") From these results:

$$C_v - C_p = 12{\cdot}37 - 12{\cdot}86 = -0{\cdot}49 = 2\beta T,$$

and since the values were calculated at 290 abs.:

$$\beta = -9{\cdot}0 \times 10^{-4}$$

At T = 290 deg. abs., Q = − 35,600, so that at T = 1,873, Q = − 38,700. The difference is therefore negligible, and no appreciable error is introduced by taking the values at ordinary temperatures.

To find the difference in the value of the equilibrium constant K:

$$\frac{d}{dt}\log K = -\frac{Q}{RT_2} \quad . \quad . \quad . \quad (8)$$

and on integrating:

$$\log\frac{K_1}{K_2} = -\frac{Q}{R}\left\{\frac{T_1 - T_2}{T_1 T_2}\right\}.$$

The ratio between the value of K at 1,600 deg. C. and K at 1,550 deg. C. is consequently:

$$\log\frac{K_1}{K_2} = \frac{38{,}700 \times 50}{2 \times 2{\cdot}30 \times 1{,}873 \times 1{,}823} = {\cdot}124$$

$$\frac{K_1}{K_2} = 1{\cdot}33.$$

Since $K = \frac{C_{CO}}{C_{FeO} \cdot C_C}$, an increase in K implies an increase in CO or a diminution in the product of the bottom terms. The steel is, however, saturated with CO, and, like all gases in solution, the saturation strength must diminish very considerably with a rise in temperature. At the finishing stage, pigging back is usually started when the carbon is in the neighbourhood of 0·17 to 0·20, so that the carbon concentration is practically constant and independent of other conditions. An increase in the value of the equilibrium constant of 33 per cent., as found above, means a reduction in the amount of ferrous oxide in solution of more than 33 per cent.

APPENDIX II.

The reaction:

$$FeO + CO = CO_2 + Fe_1 + 3.7 \text{ cal} \quad . \quad . \quad (7)$$

can be treated in exactly the same manner as the previous reaction in Appendix I, but it presents some peculiar features. To begin with, the log K from Baur and Glässner's results plotted with 1/T does not give a straight line, which implies that Q varies with temperature to an appreciable extent.

The heat of reaction at ordinary temperatures is + 3,700 cal. and the molecular heat of CO_2 is 8·9. This gives, as before:

$$2\beta T = C_v - C_p = 17{\cdot}16 - 15{\cdot}05 = 2{\cdot}11,$$

$$\therefore \beta = 3{\cdot}6 \times 10^{-3}$$

This value is unusually high. At 825 deg. C. the heat of reaction Q_{825} is:

$$Q_{825} = 3{,}400 + \beta(1{,}098)^2 + 7{,}750 \text{ cal.}$$

The equilibrium constant K has the following values:

750 deg. C.	1·56
900 deg. C.	2·51

which, calculating back by means of equation (8), Appendix I, gives

$$Q_{825} = 7{,}650 \text{ cal.}$$

This agrees very well with the previous value, found by quite a different method.

Substituting $Q_0 + \beta T^2$ in the integration of equation (8), Appendix I, the value of K at different temperatures will be:

Deg. C.	
1,200	5·8
1,300	7·5
1,400	9·5
1,500	12·1
1,600	15·2

The gas given off from a steel ingot immediately after solidification gave a ratio for K of 11·0,* and at lower temperatures 3·1 to 4·2. In the former case the temperature cannot have been far removed from the temperature of solidification, which was in the neighbourhood of 1,475 deg., and in the latter case the temperatures were probably about 700 deg. to 800 deg. C. These figures show the great importance of equilibrium conditions, and support the contentions of the author regarding the methods of estimating the gases in solution in steel.

WASTE HEAT FOR STEAM GENERATION.

The Utilisation of Waste Heat from Open-Hearth Furnaces for the Generation of Steam.†

By THOMAS B. MACKENZIE, M.I.Mech.E., Motherwell.

(*Concluded from page 569.*)

A typical analysis of the producer gas supplied to the furnaces during the above tests is:—

	Per Cent.
CO_2	8·2
CO	20·8
CH_4	3·4
H_2	13·0
N_2	54·6
	100·0

From which the amount of air and volume of products of combustion, with the theoretical amount of air required for complete combustion, can be calculated. The result combustion, with the theoretical amount of air required is shown in the following table:—

Gas Ft.³ per Ft.³.	Air for Complete Combustion.	Products of Combustion.		
		CO_2.	H_2O.	N_2.
CO_2 : 0·082	—	0·082	—	—
CO : 0·208	O_2 : 0·104	0·208	—	—
CH_4 : 0·034	O_2 : 0·068	0·034	0·068	—
H_2 : 0·130	O_2 : 0·065	—	0·130	—
N_2 : 0·546	N_2 : 0·902	—	—	1·448
1·000	1·139	0·324	0·198	1·448

1·139 volumes of air are therefore required for the theoretical combustion of 1 cub. ft. of producer gas, and will yield 1·97 cub. ft. of products of combustion all reduced to s.t.p.

A typical analysis of the waste gases entering boiler, estimated on a dry sample, is:—

	Per Cent.
CO_2	11·2
O_2	7·2
N_2	81·6
	100·0

Replacing the water vapour and separating from the N_2 that entering with the excess air, the volumes and percentages are in 1 cub. ft. of the products:—

Gas.	Cubic Foot per Cubic Foot.	Per Cent.
CO_2	0·1127	11·27
H_2O	0·0688	6·88
N_2	0·4906	49·06
Excess air	0·3189	31·89
	1·0000	100·000

The total volume of the products of combustion are with this amount of excess air 2·89 times that of the

* Journal of the Iron and Steel Institute, C.S.M., 1910, page 157.

† *Ferrum*, 12, page 78.

‡ Journal of the Iron and Steel Institute, C.S.M., 1902, page 224.

* Baraduc-Muller, *loc. cit.*

† Paper read before the Iron and Steel Institute, September 13, 1918.

producer gas when they are at the same temperature and pressure.

The mean specific heats of the gases in pound calories per cubic foot at s.t.p. have been calculated by the following Malard–Le Chatelier formulæ :—

$$CO_2 = 0{\cdot}023 + 0{\cdot}000014t \text{ deg. C.}$$
$$H_2O = 0{\cdot}021 + 0{\cdot}000009t \text{ deg. C.}$$
$$O_2 \text{ and } N_2 = 0{\cdot}0189 + 0{\cdot}0000017t \text{ deg. C.}$$

To aid the use of these formulæ, **Fig. 2, page 568, *ante*,** is given, on which the temperatures of the gases and quantities of heat in pound calories are plotted as co-ordinates. The curved lines give the values for the various gases named. To use the diagram all that is necessary is to multiply the fraction of a cubic foot of the particular gas in 1 cub. ft. of the mixture by the value of the heat contents on the vertical scale opposite the point where a vertical from the temperature cuts the curve of the gas required, when the sum of the products will give the heat contents of the mixture in pound calories per cubic foot.

The calorific value of the producer gas is 78·91 lb. calories per cubic foot, and its volume about 150,000 cub. ft. at s.t.p. per ton of fuel.

The furnace, when the whole volume of gas passed through the boiler, was delivering 950,000 ft.³ of products per hour at s.t.p., and was producing ingots at the rate of 5·94 tons per hour; its fuel consumption was therefore :—

$$\frac{\text{950,000 ft.}^3 \text{ per hour}}{\text{7,500 ft.}^3 \text{ per cwt.} \times 5{\cdot}94 \times 2{\cdot}89} = 7{\cdot}377 \text{ cwt. per ton of ingots.}$$

As the furnace was working on cold stock, and the fuel contains on an average 13·5 per cent. ash and 9·7 per cent. water, the result is fairly good.

Consideration may now be given to the theoretical principles which govern the operation of waste-heat boilers, making use of the data which have been observed in connection with the above tests to determine the constants, to enable formulæ to be constructed for fixing area of heating surface, &c. Let

- θ_1 = Quantity of heat per ft.³ in products entering boiler.
- θ_2 = Quantity of heat per ft.³ in products leaving boiler and entering economiser.
- θ_3 = Quantity of heat per ft.³ in products leaving economiser.
- V = Volume of products per hour reduced to s.t.p.
- H_1 = Area of boiler heating surface in square feet.
- H_2 = Area of economiser heating surface in square feet.
- M_1 = Modulus of heat transmission through boiler H.S.
- M_2 = Modulus of heat transmission through economiser H.S.

The amount of heat transmitted through an element of heating surface d H. will be : d H.M. θ.

The volume of products flowing past this place in an hour is V cub. ft., and the heat lost by it will be : V.$d\,\theta$.

When steady conditions have been attained these expressions must be equal to each other, therefore :

$$d\,H\,.\,M\,.\,\theta = -\,V\,.\,d\,\theta, \text{ equal to :}$$

$$\frac{d\,H}{d\,\theta} = -\,\frac{V}{M}\cdot\frac{1}{\theta} \quad . \quad . \quad . \quad (1)$$

Integrating (1) there is obtained :

$$H = -\,\frac{V}{M}\cdot\log\theta + \text{const.} \quad . \quad (2)^*$$

To determine the constant make H=0, at which place the entrance to the boiler, $\theta = \theta_1$ and the constant is :

$$\frac{V}{M}\cdot\log\theta_1.$$

Taking the integral over the whole heating surface from the entrance where $\theta = \theta_1$, to the outlet when $\theta = \theta_2$ there is obtained the equation :

$$\frac{H\,M}{V} = \log\left(\frac{\theta_1}{\theta_2}\right) \quad . \quad . \quad . \quad (3)$$

Having observed V, H, θ_1, and θ_2, the modulus M_1 can be obtained from the equation :

$$M_1 = \frac{V}{H}\cdot\log\left(\frac{\theta}{\theta_2}\right) \quad . \quad . \quad . \quad (4)$$

Finally, having found M_1 and fixed on the ratio $\frac{\theta_1}{\theta_2}$, the heating surface of any boiler to deal with V cub. ft. of products per hour can be calculated from the equation :

$$H = \frac{V}{M_1}\cdot\log\left(\frac{\theta_1}{\theta_2}\right) \quad . \quad . \quad . \quad (5)$$

The same argument applies to the economiser except that M_1, θ_1 and θ_2 are substituted for M_1, θ_1 and θ_2.

The modulus for boiler M_1 and that for economiser M_2 have been calculated from the data furnished by the tests recorded above with the results shown in the following table, viz. :—

Test.	θ_1 Lb. Cal.	θ_2 Lb. Cal.	θ_3 Lb. Cal.	Boiler. $\frac{\theta_1}{\theta_2}$	Boiler. M_1.	Economiser. $\frac{\theta_2}{\theta_3}$	Economiser. M_2.
Exp.	10·75	5·19	3·40	2·07	170·4	1·53	224·5
I.	12·65	5·59	3·66	2·26	178·3	1·53	177·2
II.	8·87	4·73	3·72	1·88	172·8	1·27	119·5
III.	12·47	6·10	3·45	2·04	162·6	1·77	237·9
IV.	9·26	6·26	5·39	1·48	169·8	1·16	117·5

* The logs are the Naperian or natural logarithms.

It will be noted that the modulus, in the case of the boilers, is fairly consistent, the average value being 170·8. If it be taken as 171 equation (5) can be put in the form :

$$\frac{\text{Volume of products per hour at s.t.p.}}{171} \times \log\left(\frac{\theta_1}{\theta_2}\right) = \text{heating surface of boiler in sq. ft.} \quad (6)$$

In the case of the economisers the results are rather inconsistent. It is, however, interesting to note that in Test III, which gives the highest value of M_2, the economiser was new and was being supplied with Loch Katrine water, which is ideal for boiler purposes. The next highest is the experimental one when the economiser was also new and supplied with Motherwell water, which is a fairly good water. The third highest, test No. I, was also supplied with Motherwell water, but the economiser had been in use for some time, so that the pipes were probably somewhat scaled. The two lowest results, tests II and IV, are both fed with water from Kilbirnie Loch in Ayrshire, and the water is rather hard.

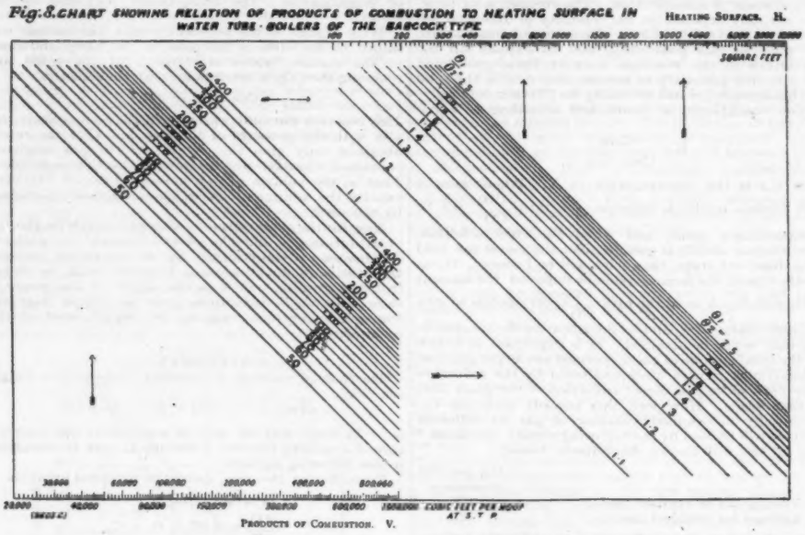
If the average of the three highest values be taken we obtain the value 213·2, or in round figures 210. Equation (5) can then be put in the form :

$$\frac{\text{Volume of products per hour at s.t.p.}}{210} \times \log\left(\frac{\theta_2}{\theta_3}\right) = \text{heating surface of economiser in sq. ft.} \quad (7)$$

To enable the results of these equations to be found by inspection diagram **Fig. 3**, above, has been prepared, on which will be found a scale at the bottom left-hand side giving values of volume of products per hour; the diagonal lines above this scale give different values of the modulus M. To the right of these are another series of diagonal lines giving different values of the ratio $\frac{\theta_1}{\theta_2}$ or $\frac{\theta_2}{\theta_3}$, as the case may be, whilst at the top right-hand side is a scale from which the appropriate area of heating surface of boiler or economiser can be read off.

The method of using the diagram is to select on the scale of volumes the value which applies to the case, pass vertically upwards to where the line cuts the value chosen as the modulus, then horizontally across to the intersection of the line giving the value chosen for the ratio of heat contents, then vertically upwards to the scale of heating surfaces, when the value required will be found.

Fig. 3. CHART SHOWING RELATION OF PRODUCTS OF COMBUSTION TO HEATING SURFACE IN WATER TUBE BOILERS OF THE BABCOCK TYPE.

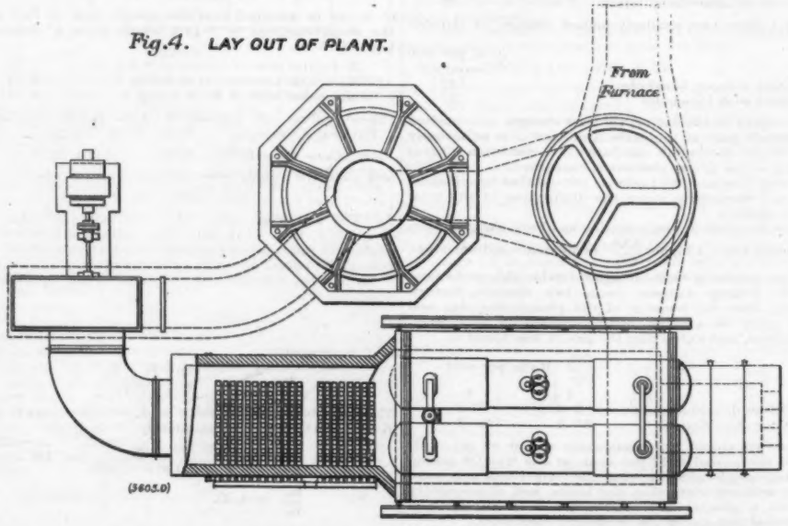


$$H = 2{\cdot}3026\,\frac{V}{m}\log_{10}\frac{\theta_1}{\theta_2}.$$

Where

- H = Heating surface in square feet.
- V = Volume of products of combustion in cub. ft. per hr.
- θ_1 = Heat contents per cub. ft. of products entering boiler.
- θ_2 = Heat contents per cub. ft. of products leaving boiler.
- m = Modulus of heat transmission through heating surface.

Fig. 4. LAY OUT OF PLANT.



Consideration may now be given to the rate of heat transmission through the boiler-heating surface. This will depend on two factors :—

(*a*) The difference of temperature between the average heat of the hot products in their passage through the boiler chamber and the water inside the boiler, constituting the heat gradient through the thickness of the material forming the heating surface.

(*b*) The speed of flow of the hot products over the heating surface.

It will be assumed, what is probably correct, that when the speed of flow is constant the rate of transmission through the heating surface of the boiler will vary directly as the heat gradient, and that when the heat gradient is constant the rate of transmission will vary directly as the speed of flow of the products. It will also be assumed that the figure obtained by dividing the average volume of products passing through the boiler chamber by the area of heating surface will be proportional, with boilers all of the same type, to the

speed of flow. With these assumptions the following table has been calculated :—

1. Test.	2. Heat Gradient.	3. Vol. per min. / H.S.	4. Product of 2 and 3.	5. Heat Transmission from Test.	6. Heat Transmission from Formula.
	deg. C.			Lb. Cal.	Lb. Cal.
Exp.	214·3	9·34	2,002	981	1,184
I.	237·4	9·39	2,416	1,390	1,256
II.	174·7	10·02	1,753	1,076	1,135
III.	280·8	9·88	2,775	1,339	1,314
IV.	198·7	17·04	3,386	1,382	1,401

Let

G = Heat gradient as defined above.
S = Volume of products per minute divided by area of heating surface as defined above.
P = G × S.
T = Heat transmitted through heating surface in pound calories per square foot per hour.

It will then be found that if the common logarithms to base 10 of P and T are plotted as co-ordinates the points will lie in a cluster through which a straight line can be drawn inclined to the horizontal at an angle whose tangent is 0·32 and which will cut the vertical axis at 2·017, from which the following equation can be derived :

$$T = 104 \times (P)^{0.32} \quad . \quad . \quad . \quad (8)$$

This equation can be written :

$$\log_{10} T = 2.017 + 0.32 \log_{10} P \quad . \quad . \quad (9)$$

in which form it is easily solved with the aid of a table of logarithms.

Values of T have been calculated for the several tests recorded in the first section of this paper and tabulated in column 6 of the foregoing table against the values from the experimental results.

It will be noted that the experimental boiler and No. 1 do not agree very closely, but that the others are in fairly close agreement.

More experimental data are, however, required over a wider range of values, and it is hoped that any of the members who may have such data in their possession will be good enough to communicate them.

It will be noted that in fixing the heating surface we determine the ratio of heat contents of the products entering and leaving the boiler chamber, whilst in determining the heat transmitted per square foot of the heating surface what we require to know is the temperature entering and leaving the boiler chamber. The temperature entering will, in the case of an existing furnace, be obtainable by actual measurement with a pyrometer, and in the case of a new furnace can be approximated to from the known results obtained with similar furnaces.

To obtain the temperature of the products leaving the chamber, having fixed upon the ratio of $\frac{\theta_1}{\theta_2}$ it will be useful to have an equation connecting temperature with heat contents in a form convenient for use.

If the analysis of waste products already given be taken as a good average sample, the equation connecting temperature with heat contents is :

$$0.1951\ t + 0.000{,}003{,}6\ t^2 = \theta = \text{heat contents per cub. ft.}$$

This quadratic equation is not particularly convenient for use, but if values are calculated, and their logarithms plotted with the logarithms of the temperature as co-ordinates an equation is obtained which is easily solved with the aid of a table of logarithms, it is :

$$\text{Log } t \text{ deg. Cent.} = 0.939\ (1.846 + \log \theta) \quad . \quad (10)$$

The following table gives values of heat contents corresponding to the most useful temperatures likely to occur in waste-heat boiler practice, and also the results obtained from equation 10 :—

Temperature Cent.	Heat Contents per Cubic Foot θ.	Equation (10).
deg.		deg.
100	1·987	103·1
200	4·046	202·2
300	6·176	299·1
400	8·379	398·4
500	10·654	499·1
600	12·996	599·4
700	15·424	706·3
800	17·912	813·0

Another point which is of interest is the question of the resistance to flow of the hot products through between the boiler tubes, and what suction, measured in water gauge, must be provided to overcome the resistance and still leave enough pull at the entrance to the boiler to maintain the draught necessary for the efficient operation of the melting furnace.

The experience which has been gained in the past has practically been with boilers fired with either solid, liquid or gaseous fuel in which there was actual combustion under the boiler.

Under these circumstances the volume of the products of combustion are not so large as where the whole products from a large smelting furnace have to be dealt with.

Making the same assumption which was made with regard to the rate of heat transmission, viz., that the rate of flow of the products is a function of the volume per minute divided by the heating surface and calling this $f(v)$, it would appear that a simple linear equation of the form :

$$0.16\ f(v) = \text{suction in inches W.G.} \quad . \quad (11)$$

will give results closely agreeing with the limited number of observations available, as the following table will show :—

f(v)	Suction entering Boiler.	Suction leaving Boiler.	Difference.	From Formula.
	W.G. in.	W.G. in.	W.G. in.	W.G. in.
9·39	0·91	2·43	1·52	1·50
9·88	1·60	3·05	1·45	1·58
10·02	1·00	2·50	1·50	1·60
17·04	1·00	3·75	2·75	2·72

More experimental data are, however, required before the curve can be accurately determined.

As none either of the boilers or economisers which were tested were prepared in any way for the test, but were taken in their actual working conditions, some of the discrepancies betwen the actual and the calculated results are no doubt due to the state of the tube surface as to freedom from deposit on the outside and scale inside.

None of the boilers above referred to were provided with superheaters, but there is no doubt that such could be quite well applied with the advantage of obtaining steam containing a greater store of energy.

With regard to the actual setting of the boiler, economiser and fan, it is important to keep the passages short and direct, avoiding all quick bends, also to do everything possible to prevent air leakage. There must also be provided plenty of explosion doors, which must be air-tight when closed. So important is the prevention of air leakage that the author is of opinion that where waste-heat boilers are to be used the air valves of the furnace should be water-sealed, as the butterfly valves usually used for air are far from being tight.

A good lay-out of the plant is shown in Fig. 4, from which it will be seen that a three-way water-sealed valve of the drum type is arranged to send the products either to the boiler or direct to the chimney, and that the fan discharges back into the chimney, as even at their low temperature, after passing over boiler and economiser, some pull could be got from the chimney to help the fan.

Collecting the more important results of the tests detailed in the first part of this paper, the following table is obtained :—

Item.	Exp.	I.	II.	III.	IV.
Heat usefully employed in boiler, lb. cal.	1,555 000	2,540,000	2,360,000	2,954,000	3,051,000
Weight of steam of dryness factor 0·95 generated per hour, lb.	2,440	3,762	3,728	4,616	4,736
Weight of steam per ton of ingots, lb. ..	1,084	949·3	855·3	1,252	796·9

The average of the above weights of steam per ton of ingots is 987·5 lb. As only one of the boilers in the above tests was receiving all the waste products of combustion, and it was too small to deal properly with the amount, and the others were only using about two-thirds of the products from their respective furnaces, there seems reason to believe that at least 1,200 lb. of steam per ton of ingots would have been obtained under more favourable conditions.

Experience has shown that in a steel works making plates and bars, and in which the power plant is not particularly up-to-date, most of the mill engines being of the simple high-pressure type, the shears being similarly driven, and even some of the live roller racks being driven by small and wasteful engines, whilst the pipe ranges are of considerable length, the steam consumption works out at 3,200 lb. per ton of ingots. Even in that case, therefore, the saving in boiler fuel which could be effected by the use of waste-heat boilers on the smelting furnaces would be 43·75 per cent. Another source of steam, which has not been dealt with in this paper, is the waste heat from the reheating furnaces. The volume of products would be less per furnace, but from some tests made it would appear that the temperature is higher. A very conservative estimate will therefore be, that under the conditions named above, a saving of 50 per cent. in boiler fuel can be made by utilising heat presently, in nearly every case, going to waste.

More experimental data are, however, necessary, and it is to be hoped that all of the members who may have such in their possession will, in the interests of engineering science, communicate them, so that the deductions which have been drawn from those herein recorded may be either confirmed, or, where necessary, modified.

In conclusion, the author desires to thank Mr. A. Maclaren, B.Sc., for his assistance in superintending the tests on boilers Nos. I to IV inclusive, and for his help in making the diagrams attached to this paper, and to Mr. Thomas, the boiler-shop manager at Dalzell Steel and Iron Works, for his assistance during the installation and testing of the experimental boiler, and for many useful hints in connection with the remaining boilers.

The following papers have already appeared dealing with the subject of waste-heat boilers, viz. :—

Where Read and Date.	Title.	Author.
I. E. & S. Scot., Glasgow, 21/3/1911	On Means for Economising Fuel and Utilising Waste Heat in Malleable Iron and Steel Works	Thomas B. Mackenzie.
Am. I. & S., L., New York, 28/5/1915	Waste-Heat Boilers for Open-Hearth Furnaces	C. J. Bacon.
Am. Soc. M.E., New York, 5 to 8/12/16	The Utilisation of Waste Heat for Steam Generating Purposes	Arthur D. Pratt.

THE PROSPECTS OF THE GERMAN IRON INDUSTRY.

At the general meeting of the large German Luxemburg Mining and Iron Works Company the chairman, Herr Hugo Stinnes, made the following statement : "This general meeting is being held at a time of serious danger for our Fatherland. We shall, of course, do our utmost to supply the Empire with means to carry on the final fight. The time of preparation for peace is before us and fills us with concern. This is not the time to speak of 'still reserves' which were to counterbalance this or that loss. The German Luxemburg Company is a strong undertaking, and will as well as any other concern be able to bear what may be imposed upon it. To secure the future as far as possible employers and employees in the Rhenish-Westphalian iron and coal industry have considered it right to co-operate for the time of reconstruction. Both sides are of opinion that we shall only be able, to some extent, to grapple with the infinite difficulties of reconstruction and demobilisation, if every internal struggle is avoided and workaday Germany shows a united front to the outer world." A representative of the shareholders pleaded for a bonus in addition to the 10 per cent. dividend and asked for information about the company's interests in Lorraine and Luxemburg. Herr Stinnes replied that the company's interest in Lorraine and Luxemburg was centred, in the first instance, in the Differdingen works, next in the majority of shares in the Saar and Moselle Mining Company, and lastly in shares in the Rümelingen Company, St. Ingbert. As matters now had developed, there could hardly be any doubt about the German Luxemburg Company having done the right thing by expanding their manufacture in the direction of more finished products. He did not approve of a bonus being declared, as in these times of upheavals even shortage of means of transport might make it impossible for the production to be forwarded at the proper time. Many iron and alkali works already had stocks far in excess of the usual quantity owing to lack of adequate means of transport.

At the general meeting of the Bochum Union it was pointed out that the industrial and financial prospects were much dependent upon political developments, which were then very uncertain. In case the peace, as was to be hoped, still left a chance of existence for the industry, prospects might be looked upon as fairly encouraging owing to the many orders in hand. The board expected that the Government would assist the works in the reconstruction period by placing adequate new orders. In this case it would be possible to give the men returning from the front remunerative work, and negotiations were pending between the works and the men's organisations about an agreement as to the steps to be taken.

At the general meeting of the Königs- and Laura-Hütte the prospects for the future were stated not to be very favourable on account, more especially, of the capricious rise in the cost of production ; ores had risen 59 per cent. and coke 56 per cent. When peace came, the reconstruction process would not present much difficulty. The 6,280 hands would all be received and employment found for them. This would be facilitated by the leaving of the prisoners of war and part of the female labour. The State would have to find the work. In order to prevent any great shortage of ready money, the Upper Silesian works had clubbed together and issued emergency vouchers for 5 marks, 10 marks and 20 marks.

The report of the Kalk Machine Company, Cologne, also pointed to the importance of the way in which the supply problem of raw materials was solved at the conclusion of peace, but otherwise the position was satisfactory ; a dividend of 20 per cent. was declared, the writings-off had been on a liberal scale for the last few years, capital was plentiful, as were orders in hand.

MANUFACTURE AND REPAIR OF RIFLES, PISTOLS, REVOLVERS AND SHOT GUNS.—In reference to the Small Arms (Manufacture and Repair) Control Order, 1918, made by the Minister of Munitions, and dated May 7, 1918, the Minister of Munitions orders as follows : (1) As from the 15th Nov. the said Order is revoked. (2) Such revocation shall not affect the previous operation of the said Order or the validity of any action taken thereunder or the liability to any penalty or punishment in respect of any contravention or failure to comply with the said Order prior to such revocation, or any proceeding or remedy in respect of such penalty or punishment. (3) The new Order of the 15th inst. may be cited as the Small Arms (Manufacture and Repair) Control (Revocation) Order, 1918.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

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Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

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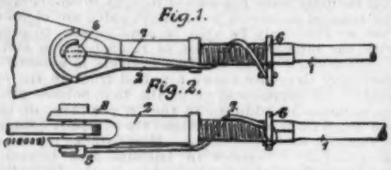
Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Act.

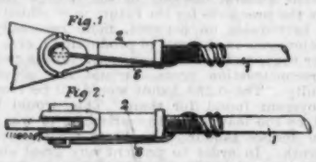
AERONAUTICS.

118,029. The Blackburn Aeroplane and Motor Company, Limited, Leeds, and J. W. Copley, Roundhay, Leeds. Aircraft. (6 *Figs.*) November 13, 1917.—The invention refers to locking devices for tension members, the object being to prevent relative rotation between such tension members and the connecting devices by which such tension members are connected to parts of the structure or to each other. In the Specification of Patent No. 118,028 there is described a locking device in which one end of a metal strip or wire is fixed by one of its ends to one of the members to be controlled, and the opposite end of the wire is bent into engagement with the other member, or is passed through the end of a pin by which the connection device is fixed to the attachment device or structure, so that any relative motion in an undesirable direction between the tension members and their connection devices is prevented by the tensioning of the wire passing around between the two members in a helical direction. The present invention provides a construction having all the advantages of the construction



above outlined, and has in addition thereto means whereby an old locking wire can be removed and a new locking wire substituted therefor without calling for soldering. To this end, and according to this invention, there is provided a collar or annulus 6 through which the threaded end of the tension member 1 is passed until the collar is at about, or it may be above, the commencement of the screwthread of the tension member, and the collar or annulus is then permanently fixed to the tension member, and it is to the collar or annulus that the end of the wire 7 is detachably fixed. Such detachable fixture for the wire is preferably effected by passing one end of the wire through a hole drilled in the collar 6 and bending that end of the wire over, for instance, a hole may be drilled through the collar parallel to the tension member; then the length of the wire below the collar can be bent around the connection device 2 or passed through a hole in the pin 5 by which the latter is anchored in such manner as to prevent rotation in an undesirable direction between the tension member and the connection device. (*Accepted August* 21, 1918.)

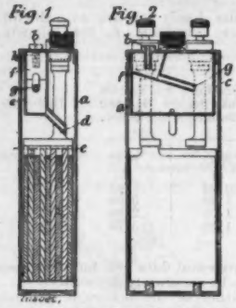
118,028. The Blackburn Aeroplane and Motor Company, Limited, Leeds, and J. W. Copley, Roundhay, Leeds. Aircraft. (2 *Figs.*) November 13, 1917.—The invention refers to locking devices for tension members, the object being to prevent relative rotation between such tension members and the connection devices by which such tension members are connected to parts of the structure or to each other, and the invention particularly refers to tension members, the end or ends of which are screw-threaded into the connection devices, which device may be forked or be otherwise formed and adapted to be fixed to some relatively stationary part. According to this invention, a metallic strip 6 of wire of any appropriate section and of any suitable metal is fixed by one of its ends to the tension



member 1 near the screw-threaded end thereof, such fixture being effected by sweating with solder and when the tension member has been screwed into the connection device 2 until at the required degree of tension, then the wire 6 is bent around the tension member in a helical direction and its end is also then bent into engagement with the connection device by being passed through any part of it, or through any member projecting from and carried by the connection device, in such manner that any relative rotation in a direction not desired between the tension member and the connection device has the effect of tightening the helical locking wire around the tension member and the connection device, and thereby in a positive and effective manner preventing relative motion between the two parts in a direction not desired. (*Accepted August* 21, 1918.)

ELECTRICAL APPARATUS.

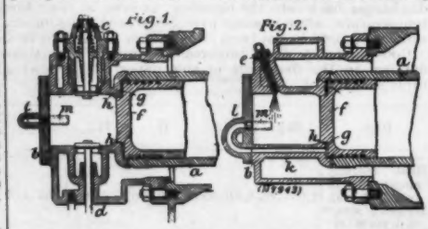
118,062. H. Dean and the Chloride Electrical Storage Company, Limited, Clifton Junction, Manchester. Electric Accumulators. (7 *Figs.*) February 26, 1918.—According to the present invention, the compartments or chambers through which the electrolyte must pass before spilling can take place through the accumulator or cell vent, are arranged above the level of the plates and the means of communication between the compartments and between the latter and the cell are so disposed that when the cell is in its normal upright position or thereabout, any electrolyte which may have passed into said compartments will return freely to the cell so that the gradual filling of the said compartments is rendered impossible. The battery cell *a* is provided in its upper part with the means for preventing spilling of the electrolyte through the vent aperture *b*. The said means comprise an outer chamber *c* communicating with the cell through an inclined tube *d*, the lower end of which is normally above the liquid in the cell, both when the latter is in its upright and in its inverted position. The normal level of the electrolyte in the cell when in its upright position is indicated by the line *e*, Fig. 1. Within the chamber *c* is a chamber *f* having a sloping bottom and an inclined tube *g* establishing communication between the two chambers. The vent



aperture *b* has a tube *h* depending therefrom to prevent electrolyte gaining access to the vent from the interior of the chamber *f*. With this arrangement the spill preventing device is completely enclosed within the walls of the cell, and electrolyte readily returns to the latter from the chambers when the cell is in an upright or nearly upright position, so that accumulation of electrolyte within the chambers is obviated. (*Accepted August* 21, 1918.)

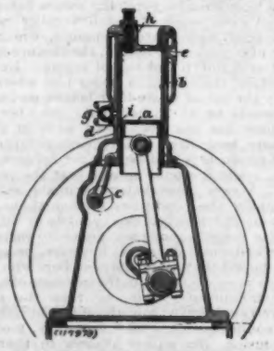
GAS ENGINES, PRODUCERS, HOLDERS, &c.

117,943. H. N. Bickerton, A. B. Balmford, and The National Gas Engine Company, Limited, Ashton-under-Lyne. Explosion Engines. (2 *Figs.*) August 8, 1917.—The invention consists in an internal-combustion engine in which liquid fuel is sprayed into a water-cooled combustion chamber, the engine being provided with a differential piston adapted to force a portion of the charge through a hot tube into the combustion space towards the end of the compression stroke. There is provided at the rear end of the engine cylinder *a* a water-cooled combustion space *b*, in which the inlet and exhaust valves *c*, *d*, are situated, and which is provided with a jet *e* for the admission of liquid fuel. A differential piston *f* is provided, the smaller end of which enters the combustion space, so that a portion of the charge is trapped between the larger portion *g* of the piston and the end *h* of the engine cylinder. From this space at the end of the cylinder, so as to convey the entrapped charge, a passage *k* leads to the back of the combustion chamber casting



on which there is provided, and in connection with the passage a U-shaped tube *l* projecting outside the chamber casting and leading to a tube *m* protruding into the combustion space in the neighbourhood of the fuel jet *e*. Before starting the engine, the projecting part *l* of the U-shaped tube is heated by a lamp. In operating the engine the fuel is injected, in a finely divided state, into the combustion chamber about the end of the compression stroke just as the small end of the piston is entering the combustion chamber, namely, about the same time as the entrapped charge is forced round the U-shaped tube, so that the hot gases emitted from the tube will meet the fuel charge in the combustion chamber, and, by the heat of the gases together with the heat of the tube, ignite the fuel. After the engine has been running for a sufficient length of time, the external heating of the tube may be dispensed with, sufficient heat being provided by the explosions in the engine cylinder. (*Accepted August* 21, 1918.)

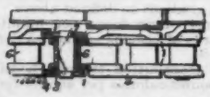
117,978. B. D. Scott, Stretford, Manchester, and W. H. Tate, Sale. Internal-Combustion Engine. (1 *Fig.*) August 28, 1917.—This invention relates to internal-combustion engines of the sleeve valve and four-stroke cycle type. The



piston *a* works within a sleeve *b*, which is reciprocated by the crank *c*, and controls the exhaust port *e* and the inlet port *d*, the amount of air admitted through the port *d* being regulated by the rotary throttle valve *g*. The fuel is admitted to the cylinder through the sprayer *h* which is opened mechanically at the required periods. The ports *i*, *j*, in the sleeve *b* and the ports *d*, *e*, in the cylinder are so positioned with relation to one another and to the movement of the sleeve and piston, that the exhaust port is uncovered just prior to the completion of the power stroke of the piston, and remains open throughout the exhaust stroke. The continued movement of the piston results in the production of a vacuous condition in the cylinder during the period in which fuel is entering through the sprayer *h* until the port is uncovered, when there is a strong inrush of air, which results in a complete diffusion of the fuel throughout the charge ready for ignition and combustion. (*Accepted August* 21, 1918.)

LIFTING AND HAULING APPLIANCES.

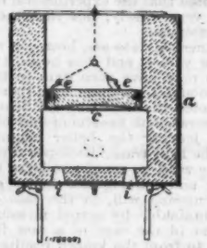
118,008. Brampton Brothers, Limited, Birmingham, and G. Wadhams, Birmingham. Conveyer Chains. (4 *Figs.*) October 9, 1917.—This invention relates to conveying chains and to that class of chain in which the interior of the bush and or the exterior of the rivet are provided with a groove containing a lubricant. The outer surfaces of the inner plates 1 are recessed to receive one-half of an asbestos or felt washer 3, the inner surfaces of the outer plates 4 being similarly recessed to receive the other half of the washer 3, the inner



periphery of the washer fitting closely against the exterior of the rivet, preventing entry of dust between these parts and also preventing entry of dust between the two plates. The inner plates 1 are united by a bush 6, whilst the outer plates are united by a rivet 7, and this rivet 7 is provided with a helical groove 8, which is filled with a non-ferrous metal which serves to lubricate the surfaces of the rivet and bush. The rivet and bush are made of steel, and being exposed to water are liable to corrosion, but it is found that the employment of a small non-ferrous surface provides a lubricant. (*Accepted August* 21, 1918.)

MINING, METALLURGY AND METAL WORKING.

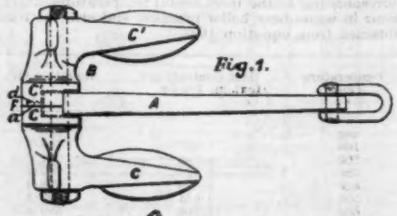
118,037. L. C. Harvey, and The Morgan Crucible Company, Limited, Battersea, London. Crucible Melting Furnaces. (1 *Fig.*) November 23, 1917.—This invention relates to crucible melting-furnaces that are heated by means of gas or oil, and has for object to render it possible to generate and localise a very high temperature over the slag area, and to this end the invention consists in providing a false cover or partition *c* which, when the crucible has been removed from the furnace *a*, is inserted into the latter and is supported in such a

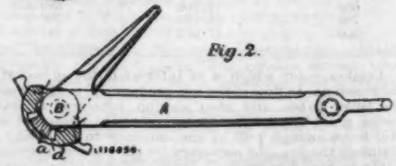


position therein as to form the cover of a relatively confined combustion chamber directly above the accumulated slag and metal, thereby allowing a high temperature to be generated locally for heating the split metal and slag to render them sufficiently liquid to escape through drain holes *i* in the furnace bottom. The cover *c* is composed wholly of refractory material and is provided with a circumferential groove in which the looped lower ends of hangers *e*, *e*, are secured, the said hangers serving for connecting the cover to the chain *d*. (*Accepted August* 21, 1918.)

SHIPS AND NAUTICAL APPLIANCES.

116,850. J. Taylor, East Boldon. Stockless Anchors. (3 *Figs.*) December 19, 1917.—The invention relates to anchors of the stockless type in which the flukes are independently pivoted to a cross-bar carried by the shank. According to the invention, the head or fluke portion of the anchor is cast or forged in two pieces, which are allowed to have a few degrees independent angular movement so as to allow the flukes of the anchor to adjust themselves to fit the ship's side. The head or fluke portion is made in two pieces C and C1, and these are held in position along with the shank A, by means of a circular steel rod B,





which passes through a hole in the two head portions C and C1, and through the shank A. The invention relates to the portion where the two head portions C and C1 meet at F, where a check arrangement is formed by the projection *a*, on head-piece C, which fits into the recess *d*, on head C1. The projection *a*, made less in length than the length of the recess *d*, to allow the head portions C and C1 to have a limitable amount of independent angular movement, the required amount of which will be governed by the form of the ship in way of hawse pipe, on which the anchor is to be housed. (*Sealed.*)